Course of Study

IN

GENERAL SCIENCE
BIOLOGY
CHEMISTRY
PHYSICS

for

Montana High Schools

Prepared and Issued
Under the Direction

of

The State Department of Public Instruction
1928

Helena, Montana

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INTRODUCTION

The work of preparation of the science course of study here presented was practically completed by Mr. Carl A. Jessen while he was a member of the state office staff in the capacity of State High School Supervisor. The reviewing of the manuscript and final revisions have been finished by him since his appointment to the position of Specialist in Secondary Education in the Bureau of Education, Washington, D. C.

The plan of the several science courses has been so carefully developed, and the purposes made so clear that it is hoped the result may be more effective teaching of science in the state, particularly in schools where the instructor is called upon to teach more than one of the science subjects or, as happens not infrequently, some subjects in an entirely different field.

MAY TRUMPER,

Superintendent of Public Instruction.

FOREWORD

This course of study is intended to serve as a manual for teachers of science in Montana high schools. Throughout its preparation two ideals have been kept constantly in mind with regard to content of courses: a degree of uniformity without standardization of subject matter; a degree of differentiation without chaos in materials of instruction. Methods are suggested; but the course would greatly fail in its purpose if the suggestions given should stifle initiative or hamper experimentation in methods.

The preparation has taken considerable time. The first step in the development of the manual consisted in distributing to a considerable number of science teachers in the state questionnaires covering its five parts. Replies to these questionnaires, study of professional literature on science teaching, analysis of texts, and conferences with teachers and administrators formed the background for the writing of the course. The manuscript was then referred to expert high school and college instructors for criticism. On the basis of their reactions final revision was made. The following science teachers assisted by returning questionnaires on one or more of the parts. The high schools mentioned are the ones in which they were employed at the time:

Lillie Doerflinger, Fergus County High School.

Lotta Dueber, Sidney High School.

Ruth Sheppard, Anaconda High School.

Sister M. Xavier, Butte Central High School.

Walter Conway, Flathead County High School.

D. C. Evans, Park County High School.

C. O. Glisson, Great Falls High School.

Rev. J. H. O'Neill, Mt. St. Charles College.

R. W. Spencer, Lima High School.

The Central Scientific Company and the W. M. Welch Manufacturing Company contributed many valuable suggestions re-

garding equipment. Special acknowledgment is due to Professors W. M. Cobleigh, F. W. Ham, and D. B. Swingle of Montana State College and to the late Professor J. E. Kirkwood of the State University for critical reading of parts of the manuscript and to Miss Sheppard and Messrs. Conway, Evans, Glisson, and W. E. Stegner, present high school supervisor in Montana, for careful review of the whole manual previous to final revision.

CARL A. JESSEN.

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PART I. INTRODUCTION

Aims With the Study of Science

Of the seven major educational objectives enumerated by the N. E. A. Commission on the Reorganization of Secondary Education* the following six are realizable in part through the study of science.

Health

Class study and discussion from a scientific standpoint of such topics as water supply, disposal of sewage, prevention of disease, right kind of exercise, importance of fresh air, good food, and sufficient sleep lead to more satisfactory personal hygiene and community sanitation.

Worthy Home Membership

Our sciences have furnished many conveniences for our homes and our social life; science study should not only make us aware of the existence of these inventions, but should also acquaint us with facts regarding their operation and care.

Vocation

The close relationship existing between scientific study and many forms of skilled labor and professional work needs only to be mentioned to be realized.

Civic Education

The role of science in promoting civic education is probably not so obvious; but there is opportunity for a much deeper appreciation on the part of our citizenship of the expert's value and importance to our national and world progress; a broader understanding of science will increase this appreciation.

Worthy Use of Leisure

Courses in general science, biology, geology, and astronomy have avocational values for the lover of the out-of-doors, while physics and chemistry open up interests in radio, photography, and general laboratory experimentation to a degree unrealizable by one who does not have the scientific background.

Finally, the laws of science should inculcate a fixed and unshakable Ethical Character reverence and respect for truth and justice; the ethical motive probably underlies science more strongly than any other school subject except literature.**

Administration of the Science Course

Science Enrollment in State and Nation

During the school year 1923-1924, 16.73% of the students in Montana high schools were enrolled in general science, 9.54% in biology, 8.25% in physics, 7.25% in chemistry, 5.42% in physiography, and 1.76% in other sciences.*** About half of the high school pupils were taking some science work. The results secured from a study conducted in 1927 by the Inland Empire Science Teachers' Association were in substantial agreement with these findings. During the school year 1921-1922, the last year for which

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* Bulletin of the U. S. Bureau of Education, 1918, No. 35. **Cardinal Principles of Secondary Education.** This publication may be secured at a cost of five cents from the Superintendent of Documents, Washington, D. C.

See Bulletin of the U. S. Bureau of Education, 1920, No. 26, **Reorganization of Science in Secondary Schools for more detailed statement on these objectives. This is the N. E. A. bulletin which will be referred to frequently in the following pages. It is for sale at ten cents a copy by the Superintendent of Documents, Washington, D. C.

***See **Eighteenth Biennial Report of the Superintendent of Public Instruction** (1924) for figures from which these percentages have been derived.

information on this subject is available, 18.27% of the high school students in the United States were taking general science, 8.93% physics, 8.78% biology, 7.40% chemistry, 6.06% hygiene and sanitation, 5.08% physiology, 4.28% physiography, and 5.51% other natural sciences.** Nearly 65% of the high school pupils were enrolled in science courses. It is evident that in both state and nation general science leads notably in enrollment while biology (including physiology, hygiene, and sanitation), physics, and chemistry follow in order.

Recommendations Regarding Selection and Sequence

In the latter part of the year 1920 the N. E. A. Commission on the Reorganization of Secondary Education published the report* of its science committee. This committee, consisting of forty-seven members, more than half of them directly connected with secondary schools, issued its recommendations after over seven years of investigation and deliberation. The report has, naturally, had a far-reaching effect in stabilizing the science curriculums of our high schools.

The science subjects recommended by the committee for large high schools allow, as one would expect, considerable variation in selection and sequence. For schools of medium and small size the recommended selection is limited to general science for ninth grade, biological science for tenth grade, and chemistry and physics for eleventh and twelfth grades.

Since the large majority of our Montana high schools are to be classified as of medium or small size, it is recommended here that the first four sciences introduced be general science, biology, chemistry, and physics. The sequence by high school grades may well be as given above; not infrequently, however, physics is given before chemistry; in small schools it is recommended that physics and chemistry be given to combined eleventh and twelfth grade classes and that these subjects be alternated by years as indicated in the *Manual on Organization and Administration of Montana High Schools.**** In large schools the science program will be enriched by the addition of courses in other science subjects, such as physiography and geology, and by differentiated or extended courses within the fields of biology, chemistry, and physics.

Science Requirement for Graduation

In discussing science units required for graduation, one enters a field of controversy and varied practice. Some schools demand the earning of a certain total amount of science credit without specifying in further detail; others require some definite science or sciences; still others, especially among the larger schools, make the requirement depend upon the curriculum which the student is pursuing.

Seldom is a high school found which does not require of every graduate that at least one unit of credit in science be included among the fifteen or sixteen presented for graduation. More frequently, in view of what is usually considered a reasonable college requirement, two units of credit in laboratory science are demanded for graduation in all except definitely vocational curriculums. In view of the importance of science study it is recom-

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* See page 13 for reference to this report.

Figures secured from Table 32 of the Bulletin of the U. S. Bureau of Education, 1924, No. 7, **Statistics of Public High Schools, 1921.

***See pages 11-17 of this manual.

mended that at least one, and preferably two, units of credit in science be required for graduation. Partly for this reason, but principally because of inherent values of general science study, the recommendation is here made that all Montana high school pupils be required to compete one year's work in general science in the ninth or at latest in the tenth grade. It is recommended further that in so far as possible one additional unit of science credit be demanded for graduation. Exception to this rule may be made with students completing home economics or agriculture curriculums; in such cases two units in these departments may be substituted for the regular science credits, although it is desirable even under these conditions that some study of the regular science subjects be pursued.

Time Allotment

The practice still followed in a few schools of offering certain sciences without special laboratory time should be discontinued. All natural science requires laboratory work for its successful teaching and, since much of this laboratory work cannot be completed successfully in a forty or forty-five minute period, the administrative device of assigning three recitation and two double laboratory periods each week to science subjects has been quite generally adopted. In the absence of suggestion regarding a better plan of operation, these time allotments have been stated as minimum time requirements in number 17 of the standards for accrediting. In schools employing the lengthened period this requirement will be satisfied if not less than 280 minutes of classroom time are given each week to each science.

Recitation and Laboratory

Distribution of Recitation and Laboratory Time

It is not necessary to suppose nor does it follow from what has been said about time allotment that recitation and laboratory respectively will occupy exactly three-sevenths and four-sevenths of the time given to science. Undoubtedly there are weeks in every science course when two double periods are not needed for experimental work; on the other hand there are times when more than the allotted 160-180 minutes each week should be used. The skillful instructor will not be bound by distinctions between recitation and laboratory, but will aim to keep these two parts of science study supplementary in material and concurrent in time. Demonstration experiments will occasionally consume part or all of a forty-five minute period; a double period may be used partly for recitation, partly for laboratory; sometimes tests, field trips, or group reports with discussion may take up ninety minutes; when an experiment is concluded, as not infrequently happens, in less than ninety minutes, the remaining time of the period may profitably be given to supervised study.

The distinction between recitation and laboratory is unfortunate if it causes teachers unduly to anticipate, postpone, or neglect laboratory work for recitation or vice versa. The problem is that of securing class reaction to certain material. Explanation, illustration, experimentation, demonstration, field trips, individual projects, reports, working of problems, and other activities may be necessary for adequate presentation. The instructor should determine the most advantageous distribution of time within the 280 or more minutes allotted to the science class each week; but he should not attempt to disarrange the school program by asking for a double period on a

day when a single science period is scheduled; neither should he take upon himself authority to excuse his class to the study hall instead of personally supervising them for the full laboratory time on laboratory days.

Science Material Outside the School: Demonstrations, Home Projects, Field Trips

Just as laboratory work should not be limited to two double periods a week, so it should not be confined to one or two rooms in the school building or to apparatus supplied and owned by the school. The practical science course uses the world or as much of it as is available for laboratory. Many of the practical applications of science may be brought to the classroom by the instructor and pupils; many of them may be studied as home projects by individual pupils; many are of such nature that the class must be brought to them. The alert instructor will continually be enlivening theoretical explanation with display of devices, appliances, and new inventions secured from the homes of pupils and the various shops about town; almost every textbook gives suggestions for home projects; field trips for study of physiography of the neighborhood, plant life, animal life, electric power plant, pumping station, health office or hospital, fire station, and various manufacturing and industrial processes have values which should by no means be overlooked by science instructors.

Demonstration, Group, and Individual Experiments

Of the experiments performed in the school building some will be carried on in the recitation room, others in the laboratory; some will come during single, others during double periods; some will be on the demonstration order, others will consist of individual or group work. There is an unfortunate tendency on the part of some science instructors to require almost no experiments in which the pupils themselves manipulate the apparatus. This criticism applies especially to courses in general science. Seeming justification for such neglect is found in the insufficiency of apparatus, the lack of dexterity on the part of pupils in handling apparatus, or the time saving element with demonstration experiments. Experimentation has not as yet established definitely the relative values of laboratory demonstration and individual or small-group labortory work. Under these conditions it is sound practice to vary the laboratory method, but certainly not to eliminate the pupil-performed experiment.

Notebooks

A laboratory experiment should be well planned in advance, should be carefully supervised while in progress, and should be written up before the pupils leave the room. The last mentioned practice will be found to have two advantages: the teacher is given opportunity for helping the pupil when aid is necessary; the pupil can secure help from no source without the teacher's knowledge. A practice very general among successful science teachers is never to allow the science notebooks to be taken from the science laboratory. Wherever drawers or laboratory lockers are provided, notebooks, pencils, pen and ink may be kept in the individual lockers at all times except when used in the laboratory; if the instructor carries one or more master keys, the pupils need nc individual locker keys. Another method is to have the sheets on which the experiments are recorded dropped into a locked box; any sheet found incorrect is returned to the pupil for correction; if correct, it is kept by the instructor until the end of the semester or year.

At the beginning of the year the instructor's check of notebooks should

be frequent, preferably after every experiment. Clearness and accuracy of statement together with neatness in form should be demanded at all times. As pupils become accustomed to the subject, checks may be made at the close of every week or at the end of every two weeks. Pupils should be required to bring their notebooks up to date before each monthly or six-week test.

There is no scheme known for appreciably lightening the work of checking notebooks; this is a type of drudgery to which the teacher commits himself when he decides to teach laboratory science. The labor connected with correcting any kind of written work may be reduced to a minimum by refusal to waste any time with checking slovenly or careless work. This plan also has other obvious and commendable features. If the science instructor will make clear to the pupils those points of uniformity on which he will insist and then will spend no time with correcting notebook sheets which are illegibly written or which otherwise do not meet these demands, he will save himself many hours of useless labor. One teacher in the state thus describes form requirements placed in his classes:

> "By form I mean blocking out the work so that it looks neat; using a half-inch margin and keeping it straight, not writing close to drawings, writing on the lines, paragraphing, keeping columns of figures with the decimal points in a row—in short, making the work look as much as possible like a printed page."

Looseleaf notebooks have in general replaced bound ones. The combination notebook-manual is found not infrequently. The printed manual is objectionable when it attempts to do most of the work for the pupil, thus confining his activities to answering questions asked in the manual. Many teachers of experience prefer to prepare their own laboratory directions, using an unprinted sheet in a looseleaf notebook for the writing up of the experiments. Plain, ruled, graph, and drawing papers are used as demanded by the nature of the various exercises. Artistry in the drawings is not necessary although it may be desirable. Ink should be used throughout except in drawings.

Some teachers require that all experiments be written up according to a certain outline. Such outlines usually group the laboratory activities around three or more main heads; such as, (1) purpose, object, or problem; (2) materials, apparatus, chemicals, or reagents; (3) directions, procedure, method, tests, or manipulations; (4) results, computations, or observations; (5) conclusions. Other heads appearing in such outlines are studies, questions, equations, commercial uses, drawings, reports, and references. Many excellent teachers will use no set outline, preferring to have the pupil organize as well as write each of his notebook reports. This practice is not recommended to the inexperienced teacher. Whether or not pupils are required to have their notebook statements conform to an established outline, they should early be made acquainted with this logical order of procedure in reporting an experiment; especial stress should be laid upon the great importance of observations and conclusions as contrasted with description of materials necessary for the performance of an exercise.

The following directions copied from the blackboard of a science laboratory in the state indicate one teacher's methods of getting notebook results:

"Your notebook should contain a record of:

A. What you actually *do.*

B. What you actually *observe.*

C. What conclusions you draw from your own experimental facts.

"Use simple straightforward English. Do not waste words.

"Do your own figuring in pencil in space provided.

"Use ruler and stencil to draw apparatus and 'set-up.'

"All experiments must be written up in notebooks before you leave laboratory.

"Corrections must be made before an experiment is accepted.

"When an experiment is completed leave your apparatus in good condition. Report anything which seems to be out of adjustment."

The New-Type Examination

The new-type examination is making headway in science as in other subjects of instruction. Experience indicates that it should supplement but not supplant the traditional kind of examination question. The following books contain chapters on the construction and scoring of tests of the objective type:

Odell. *Traditional Examinations and New-Type Tests.* (1928). Century.

Ruch. *The Improvement of the Written Examination.* (1924). Scott.

Ruch and Stoddard. *Tests and Measurements in High School Instruction.* (1927). World.

Smith-Wright. *Tests and Measurements.* (1928). Silver.

Symonds. *Measurement in Secondary Education.* (1927). Macmillan.

Where it is desired to give standardized tests, the following are recommended for the various science subjects:

GENERAL SCIENCE

Dvorak. *General Science Scales.* World.

Ruch-Popenoe. *General Science Test.* World.

BIOLOGY

Michigan Botany Test. Public School Publishing Co.

Ruch-Cossman. *Biology Test.* World.

CHEMISTRY

Columbia Research Bureau Test in Chemistry. World.

Gerry Test of High School Chemistry. Harvard University Press.

Glenn-Welton Chemistry Test. Earl R. Glenn, Lincoln School of Teachers' College.

Powers General Chemistry Test. World.

PHYSICS

Columbia Research Bureau Test in Physics. World.

Glenn-Osburn Physics Test. Earl R. Glenn, Lincoln School of Teachers' College.

Iowa Physics Tests. Public School Publishing Co.

Equipping for Science

Textbooks

Following is a list of texts in various science subjects. One text should usually be adopted as basal and a copy of it placed in the hands of each pupil in the class; as many as possible of the remaining texts should be secured for the science or general library of the school.

GENERAL SCIENCE

Barber. *First Course in General Science.* Holt.*
Caldwell and Eikenberry. *Elements of General Science.* Ginn.
Clark. *An Introduction to Science.* American.
Coulter. *Elementary Science.* Scribners.
Elhuff. *General Science.* Heath.
Fall. *Science for Beginners.* World.
Hessler. *The First Year of Science.* Sanborn.
Hodgdon. *Elementary General Science.* Hinds.
Hunter and Whitman. *Civic Science in the Home.* American.
Hunter and Whitman. *Civic Science in the Community.* American.
Lake. *General Science.* Silver.
Pease. *General Science.* Merrill.
Peterson. *Studies in Science.* Row Peterson.
Pieper and Beauchamp. *Everyday Problems in Science.* Scott.
Smith and Jewett. *Introduction to the Study of Science.* Macmillan.
Snyder. *Everyday Science.* Allyn.
Tower and Lunt. *The Science of Common Things.* Heath.
Trafton. *Science of Home and Community.* Macmillan.
Van Buskirk and Smith. *The Science of Everyday Life.* Houghton.
Washburne. *Common Science.* World.
Webb and Didcoct. *Early Steps in Science.* Appleton.
Weckel and Thalman. *A Year in Science.* Row Peterson.

BIOLOGY

Bigelow. *Applied Biology.* Macmillan.
Clement. *Living Things.* Iroquois.
Gruenberg. *Elementary Biology.* Ginn.
Hodge and Dawson. *Civic Biology.* Macmillan.
Hunter. *Civic Biology.* American.
Hunter. *Essentials of Biology.* American.
Kinsey. *An Introduction to Biology.* Lippincott.
Moon. *Biology.* Holt.
Peabody and Hunt. *Biology and Human Welfare.* Macmillan.
Peabody and Hunt. *Elementary Biology.* Macmillan.
Smallwood and Others. *Practical Biology for High Schools.* Allyn.
Trafton. *Biology of Home and Community.* Macmillan.
Waggoner. *Modern Biology.* Heath.

CHEMISTRY

Black and Conant. *Practical Chemistry.* Macmillan.
Blanchard and Wade. *Foundations of Chemistry.* American.
Bradbury. *A First Book in Chemistry.* Appleton.
Brownlee and Others. *First Principles of Chemistry.* Allyn.
Dull. *Essentials of Modern Chemistry.* Holt.
Gray and Others. *Fundamentals of Chemistry.* Houghton.
Greer and Bennett. *Chemistry for Boys and Girls.* Allyn.
Hessler and Smith. *Essentials of Chemistry.* Sanborn.
McPherson and Henderson. *Chemistry and Its Uses.* Ginn.
Newell. *General Chemistry.* Heath.

* See **Library Manual for Montana High Schools** (pages 43-45) for full names and addresses of publishing firms.

PHYSICS

Black and Davis. *Practical Physics.* Macmillan.

Carhart and Chute. *Practical Physics.* Allyn.

Fuller, Brownlee, Baker. *Elementary Principles of Physics.* Allyn.

Garton. *A High School Course in Physics.* Appleton.

Hoadley. *Essentials of Physics.* American.

Mann and Twiss. *Physics.* Scott.

Millikan and Gale. *Practical Physics.* Ginn.

Reed and Henderson. *High School Physics.* Lyons.

Manuals

Most texts have accompanying laboratory manuals bound separately. General science texts frequently have the laboratory manual incorporated as part of the text. Some texts are bound with or without laboratory manual. In addition laboratory manuals without accompanying texts are published for various science subjects by the following companies.

Atkinson Mentzer Co., Chicago.

Harter School Supply Co., Cleveland.

Iroquois Publishing Co., Chicago.

L. E. Knott Apparatus Co. (National Notebooks), Boston.

Lyons and Carnahan, Chicago.

W. M. Welch Mfg. Co., Chicago.

Pupils' Supplementary Reading

Elaborate lists of reference books on scientific subjects may be secured from numerous sources. Those wishing more extensive lists than the one here given are advised to consult lists issued by book companies, libraries, and library organizations; the various library and science manuals issued by state departments of public instruction usually contain recommendations regarding science reference books; two excellent lists appeared in the *Monthly Guide for Science Teachers,* March, 1922; a very complete list appeared in U. S. Bureau of Education Bulletin, 1925, No. 13, *Bibliography of Science Teaching in Secondary Schools.* Suggestions for addition of new books may be gained from reviews appearing in science journals, some of which are listed later in this chapter. The following list is much restricted; effort has been exerted to make it highly selective.

Bird. *Modern Science Reader.* Macmillan.*

Bodmer. *Book of Wonders.* Casper.

Bolton. *Famous Men of Science.* Crowell.

Bridges. *Th Young Folks Book of Inventions.* Little Brown.

Brisbane. *Today and the Future Day.* Albertson.

Brownlee. *Chemistry of Common Things.* Allyn.

Burns. *Story of Great Inventions.* Harper.

Caldwell and Slosson. *Science Remaking the World.* Harper.

Clements. *Rocky Mountain Flowers.* Wilson.

Collins. *Boys' Book of Experiments.* Crowell.

Collins. *A Bird's Eye View of Inventions.* Crowell.

Conn. *Bacteria, Yeasts and Molds in the Home.* Ginn.

Coulter and Nelson. *New Manual of Rocky Mountain Botany.* American.

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* See **Library Manual for Montana High Schools** (pages 43-45) for full names and addresses of publishing firms.

Cressy. *All About Engines.* Funk.
Cressy. *Discoveries and Inventions of the Twentieth Century.* Dutton.
Darrow. *Boys' Own Book of Inventions.* Macmillan.
Darrow. *Thinkers and Doers.* Silver.
De Kruif. *Microbe Hunters.* Harcourt.
Downing. *Source Book of Biological Nature Study.* U. of Chicago Press.
Duncan. *Some Chemical Problems of Today.* Harper.
Duncan. *The New Knowledge.* Laidlaw.
Forman. *Stories of Useful Inventions.* Century.
Good. *Laboratory Projects in Physics.* Macmillan.
Harwood. *New Creations in Plant Life.* Macmillan.
Hogan. *The Outline of Radio.* Little Brown.
Houston. *Wonder Book of Light.* Stokes.
Houston. *Wonder Book of Magnetism.* Stokes.
Lassar-Cohn. *Chemistry in Daily Life.* Lippincott.
Lynde. *Physics of the Household.* Macmillan.
Martin. *Modern Chemistry and Its Wonders.* Van Nostrand.
Martin. *Triumphs and Wonders of Modern Chemistry.* Baker & Taylor.
Mills. *Letters of a Radio Engineer to His Son.* Harcourt.
Mills. *Within the Atom.* VanNostrand.
Moore. *Public Health in the United States.* Harper.
Roth. *First Book of Forestry.* Educational.
Sadler. *Chemistry of Familiar Things.* Lippincott.
Sloane. *Liquid Air.* Henley.
Slosson. *Chats on Science.* Century.
Slosson. *Creative Chemistry.* Century.
Slosson. *Easy Lessons in Einstein.* Harcourt.
Slosson. *Keeping up with Science.* Harcourt.
Talbot. *Moving Pictures.* Van Nostrand.
Weed. *Chemistry in the Home.* American.
Williams. *How It Is Done.* Nelson.
Williams. *How It Is Made.* Nelson.
Williams. *How It Works.* Nelson.
Williams. *Wonders of Science in Modern Life.* Funk.
Winslow. *Fresh Air and Ventilation.* Dutton.
Winslow. *Man and the Microbe.* Funk.
Zerbe. *Automobiles.* Cupples & Leon.

A large variety of government bulletins on such subjects as public health, agriculture, home economics, weather forecasting, geology, aeronautics, patents, engineering and chemical warfare can be secured from the proper governmental bureau or from the Superintendent of Documents, Washington, D. C. Price list No. 31 issued from time to time by the Government Printing Office gives the titles and prices of available government publications relating to education. A considerable number of well written books on science subjects are contained in the *Nature Library* (Doubleday) and the *Romance Series* (Lippincott).

Teachers' Reference Books

The teacher of science should have as reference books some more advanced texts than are generally placed into the hands of pupils. The importance to the instructor of having available college texts in biology, chemistry, physics, and other sciences cannot be overestimated. In addition the following specialized professional books will be found of great aid:

Bigelow. *A Teacher's Manual of Biology.* Macmillan.

Downing. *Teaching Science in the Schools.* U. of Chicago Press.

Eikenberry. *The Teaching of General Science.* U. of Chicago Press.

Frank. *How to Teach General Science.* Blakiston's.

Ganong. *The Teaching Botanist.* Macmillan.

Gruenberg. *Manual of Suggestions for Teachers* (Biology). Ginn.

High Schools and Sex Education. U. S. Public Health Service.

Lloyd & Bigelow. *The Teaching of Biology.* Longmans.

Loevenguth. *General Science Syllabus.* World.

Mann. *The Teaching of Physics.* Macmillan.

N. E. A. Report of the Committee on Reorganization of Science, Bulletin 1920, No. 26, U. S. Bureau of Education. (Sold at price of 10 cents by Government Printing Office, Washington, D. C.)

Rusk. *How to Teach Physics.* Lippincott.

Sanford. *How to Study.* Illustrated Through Physics. Macmillan.

Smith and Hall. *The Teaching of Chemistry and Physics.* Longmans.

Sutherland. *The Teaching of Biology.* Scott.

Trafton. *Teaching of Science in Elementary Schools.* Houghton.

Twiss. *Principles of Science Teaching.* Macmillan.

Twiss. *Teaching of a Science.* Houghton.

Woodhull. *The Teaching of Science.* Macmillan.

Woolatt. *Laboratory Arts.* Longmans.

Teachers' and Pupils' Magazines

Many of the new scientific discoveries, inventions, applications, and commercial uses are of such general importance and interest that articles regarding them appear in our newspapers and magazines. There are in addition a number of magazines which take science and scientific development for their field. Some of these periodicals should be made available for every science class and instructor. Among the principal magazines for the science class are the following:

Current Science, 40 South Third Street, Columbus, Ohio.

National Geographic Magazine, National Geographic Society, Washington, D. C.

Nature Magazine, 1214 Sixteenth Street N. W., Washington, D. C.

Popular Mechanics, 6 North Michigan Ave., Chicago.

Popular Science Monthly, 225 W. 39th St., New York.

Scientific American (with Supplement), 233 Broadway, New York.

The following magazines are of more especial value to teachers:

General Science Quarterly, Salem, Mass.

Journal of Chemical Education, Easton, Pa.

School Science and Mathematics, Smith and Turton, Chicago.

The Science Classroom, 225 W. 39th St., New York.

Still further specialized fields of science are treated in such magazines

as *Wireless Age, Engineering News, Nature Study Review, Bird Lore, Good Housekeeping, Radio News,* and the like.

Visual Instruction · It may be argued that visual instruction does not belong more especially to science than to other school subjects, but the fact remains that more progress and development in visual education materials have taken place here than in other fields. To picture collections and stereoscopic views of a few years ago we have added much expensive equipment of motion picture machines and of lanterns for projection of lantern slides, microscopic slides, and opaque objects.

The difficulty encountered some years ago in securing suitable films and slides has to considerable extent been overcome although the expense of these materials continues to hinder the development of visual instruction. Introduction has been obstructed also by handicaps and problems in connection with the darkening of the room, a process which frequently consumes valuable time, results sometimes in difficulties with discipline, and is usually objectionable from the standpoint of ventilation. Within the last few years there have been developed translucent screens for daylight use and lanterns for the projection of slides, films, and opaque objects on these screens. Transparent slides and films may be projected with entire success on the classroom blackboard if one or two of the shades near the front of the room are drawn.

Three companies whose work with projection apparatus has been widespread and progressive without being of unbalanced promotional flavor are Bausch and Lomb Optical Co., Rochester, N. Y.; Eastman Kodak Co., Rochester, N. Y., and Spencer Lens Co., Buffalo, N. Y. In recent years a number of companies have entered the motion picture machine field.

Slides and films are obtainable from a wide variety of sources. The Department of Agriculture, War Department, Navy Department, and Bureau of Mines of the Interior Department have films and slides of scientific interest which may be borrowed at no charge except for transportation. U. S. Bureau of Education Bulletin, 1924, No. 8, *Visual Education Departments in Educational Institutions* indicates extension departments and larger individual school systems which have special visual education officers in charge; slides and films may be rented from some of these. The names of commercial producers, only incidentally interested in education, are known to everyone. The Society for Visual Education, 327 So. LaSalle St., Chicago, has for distribution films closely connected with various school subjects including science; their slides come in so-called picturols; the Society is also distributor for Red Cross films and slides. The Keystone View Co., Meadville, Pa., has for years been a leader in the production of stereoscopic views and lantern slides. School supply and apparatus companies frequently carry films and slides on scientific subjects. Manufacturing and industrial plants issue advertising slides and films descriptive of methods of manufacture; a number of firms and corporations have prepared exhibits tracing the process of manufacture from raw material to finished product.*

* Those interested in keeping up-to-date on developments in visual education will do well to subscribe for the monthly magazine **Visual Education**, 5 So. Wabash Ave., Chicago. Following a series of consolidations **Visual Education** now is the successor of **Moving Picture Age** and **The Educational Screen** and is the spokesman for the National Academy of Visual Instruction, The Visual Instruction Association of America, and the Society for Visual Education. Especially valuable is the monthly column on film service. For bibliography on visual education see Library Leaflet No. 18, issued March, 1923, by the U. S. Bureau of Education.

The Classroom

The science classroom should be located near the laboratory; if two laboratories are provided the recitation room may well be placed between them. Heating, lighting, and ventilating conditions should not be inferior and need not be different from those of other classrooms. It is preferable that the seats be raised in order that pupils may without leaving their chairs readily observe demonstrations carried on at the teacher's desk. The instructor's desk—it need not be expensive and can be made locally if desired—should have uprights for support of crossbars; in case pupils' desks are not raised it is advisable to have the instructor's desk so large that all pupils of the class can find room around it for unobstructed observation. Blackboard should extend along the entire front of the room and as far back on the side walls as convenient. A science bulletin board and projection apparatus are so important as to be almost essential.

The Laboratory

It is desirable that a separate laboratory be provided for each science. This situation is ideal but unattainable except in larger schools. In schools where it is necessary to provide two science laboratories it is recommended that combination of general science and physics be made in one laboratory and of biology and chemistry in the other. A greater number of schools will have only one laboratory and quite frequently the laboratory will be used also as a recitation room. Whatever inconveniences may attend this latter situation one advantage results; namely, that in the union practically all reason for lack of concurrency between recitation and laboratory work has disappeared.

The location of laboratories is usually determined at the time of construction of buildings; sometimes it may be possible to remodel and rearrange rooms. Laboratories should be well ventilated and lighted. Basement rooms are especially objectionable if they are less than half above ground. Where the laboratory is already housed in poorly lighted and inadequately ventilated basement rooms the situation may be considerably bettered by the enlargement of windows and the digging of light pits approximately three feet wide immediately outside the windows.

The lighting of biology rooms is especially important in view of microscopic work which should be done; sunlight is desirable but not essential. Both biology and chemistry rooms should be unusually well ventilated. Attempt at added ventilation through fume hoods is frequently made in chemistry laboratories; experience indicates, however, that a hood is of little value except with some kind of forced ventilation; enough open windows and a corner location are more important than fume hoods to the chemistry laboratory. The device of sprinkling ammonia on the floors will be found useful whenever the class is working with obnoxious gases.

Many laboratory furniture and apparatus companies will furnish charts and suggestions for laboratory layouts; consequently, school officials contemplating the equipping of biology, physics, or chemistry laboratories will do well to correspond with their favorite equipment firm. Since many of the ready-made plans for laboratory layouts take for granted that gas, electricity, water, and sewer connections are available, the following suggestions may prove of some value to schools not having these conveniences.*

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* Bulletin No. 22, 1927 of the United States Bureau of Education, entitled **Laboratory Layouts for the High School Sciences** is now available. This bulletin may be procured by sending 15c to the Superintendent of Documents, Government Printing Office, Washington, D. C.

Wherever gas is available there should be provided for every two pupils—preferably for every pupil—a Bunsen burner with two and one-half to three feet of rubber tubing. Where commercial gas is not available various substitutes may be introduced.

A gas-generating machine may be secured and the gas prepared at the school. These machines are usually of the acetylene or gasoline generating type. The Detmer Manufacturing Company, 2508-2520 Archer Ave., Chicago, and the Acetylene Stove Manufacturing Company, 1265 West Second Street, Cleveland, supply acetylene gas generating machines. Gasoline gas-generating machines may be obtained from Tirrill Gas Machine Lighting Company, 50 Church Street, New York City, and from Matthews Gas Machine Company, 6 East Lake Street, Chicago.

The cost of a gas machine may be prohibitive. In such cases compressed gas tubes may be purchased. Acetylene or prest-o-lite gas tanks may be secured through the local garage. The Northwestern Blau-Gas Company of Minneapolis and the Omaha Blau-Gas Company of Omaha will supply drums of blau-gas.

If no one of the three methods mentioned above for providing laboratory heat is practicable the final expedient is that of lamps. For general science four-ounce or larger alcohol lamps will be found sufficient. For chemistry and physics gasoline blast torches must be provided in addition. Small kerosene stoves or electric hot plates will be found useful in the laboratory.

Much of the electricity needed in the laboratory is secured from batteries. Electrical machines and electric lighting, however, are best demonstrated on 110 volt circuits. Where possible both alternating and direct current electricity should be made available in the laboratory.* Where commercial electric power can not be secured storage batteries or dry cells should be substituted. A three cell lead storage battery, a five cell Edison storage battery, or a battery of four dry cells connected in series will furnish current at about six volts. Under these circumstances motor and electric light apparatus operating on the lower voltages will have to be secured for electrical experiments in general science and physics.

Where city water is not available it is recommended that the laboratory water supply be kept in an earthenware jar with faucet at bottom. Such jars are used for drinking water fountains in many of our schools; they are unsatisfactory as reservoirs for drinking water, but serve well as containers for laboratory water supply.

Each chemistry table should be provided with two sinks in the table or with a drain running lengthwise down the middle to a sink at the end of the table. At least one sink is necessary for the biology laboratory. If no sewer connection is possible, earthenware jars may be substituted for sinks. Every laboratory should be provided with refuse pails with patent covers similar to those found in dental and medical offices.

Tables of various types suited to the different sciences are for sale by school furniture and supply houses. Well constructed home-made tables of soft wood are satisfactory if the tops are well put together of heavy material

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* A Motor Generator Outfit with an A. C. Motor and D. C. Generator which will furnish simultaneously 220 watts of direct current at 110 volts and 45 watts of direct current at 7½ volts may be purchased at a cost of approximately $150; this equipment is excellent for those schools which can afford it.

at least one and one-half inches thick. They should be kept in good condition by the application of acid-proof paint every three years; the acid-proof paints or dressings may, as desired, be bought or prepared locally. Chemistry and biology tables should supply a drawer and a small cupboard for each student. A minimum table space of 2½ x 1½ feet must be furnished each pupil. The small table accommodating only two pupils is much to be preferred over the large table; small schools find such equipment doubly advantageous since the laboratory can then be made more satisfactory for recitation purposes.

For seating the class, tablet arm chairs or comfortable stools are preferred by most teachers. In general science and physics laboratories swinging stools may be fastened to the tables. Benches under the windows and against the walls are useful especially where no chairs are supplied.

Provision must be made in the laboratory for the storage of apparatus. It is false economy to leave costly apparatus lying about to be broken, to deteriorate, and sometimes to be carried away. The separate stockroom with necessary shelves is the safest, least expensive, and most convenient storage place for laboratory apparatus. The built-in cabinet with glass doors is very acceptable; failing that, the special cabinet with doors which can be locked is satisfactory. One school in the state displays the more elaborate pieces of apparatus in a show case bought from a merchant who went out of business. The laboratory may, according to the ideals of the instructor, be made a neat and orderly place, inspirational to pupils, teachers, and visitors, or it may degenerate into a junk shop.

Not a great deal of blackboard space is needed in the laboratory but some should be provided. A blackboard in sections which can be raised and lowered is highly serviceable. An aquarium is so advantageous that it should not be omitted from the biology laboratory. Every laboratory should be equipped with such safety devices as a first-aid kit and one or more fire extinguishers. A bulletin board is useful. Apparatus such as wet and dry bulb thermometer, barometer, and the like may be placed in the room.

An inventory of apparatus and equipment in each laboratory should be prepared and kept up to date by check not less often than once each year; the check had best come toward the close of the semester or school year. The school budget should make provision for replacement of broken or obsolete apparatus and for growth of the laboratory from year to year by purchase of as much as possible additional material recommended in the apparatus lists found with individual science courses discussed later in these pages.

Equipment for the laboratories should be ordered during the spring or summer for delivery before the opening of school in the fall. It is usually advisable to order in standard lots; with chemicals it is frequently true that the extra work in breaking up standard packages materially increases the cost above the value of the chemicals. Many general school supply houses deal in laboratory supplies. The following firms do a more specialized business; their catalogs should be kept on file in science laboratories.

Central Scientific Company, Chicago.

Apparatus for all secondary school sciences. Projection materials.

Chicago Apparatus Company, Chicago.

Agriculture, biology, chemistry, physics.

C. H. Stoelting Company, Chicago.
Physiology and psychology. Projection materials. Charts and psychological tests.

Denoyer-Geppert Company, Chicago.
Biology. Projection materials. Charts and models.

Denver Fire Clay Co., Denver.
Chemistry.

E. H. Sargent Co., Chicago.
Biology, chemistry, physics.

E. H. Sheldon and Company, Muskegon, Mich.
Laboratory furniture.

General Biological Supply House, 761 E. 69th Place, Chicago.
Biology. Models, slides, instruments, microscopes. Preserved and live specimens.

Kewaunee Manufacturing Company, Kewaunee, Wis.
Laboratory furniture.

Kuy-Scheerer Corporation, 404-410 West 27th St., New York.
Biology, physiology, hygiene, anatomy. Charts and models.

L. E. Knott Apparatus Company, Boston.
Apparatus for all secondary school sciences. Projection materials. Science manuals.

Leonard Peterson and Company, Chicago.
Laboratory furniture.

W. M. Welch Manufacturing Company, Chicago.
Apparatus for all secondary school sciences. Projection materials. Science manuals.

PART II. GENERAL SCIENCE

Experimentation with general science may be traced back to the closing years of the preceding century when in a few schools general courses of various types were introduced preliminary to study of the special sciences which had taken complete possession of the science program. Gathering force after 1910 the general science movement spread until today the enrollment in general science is twice that in any specialized science.

Principles of Organization

While general science has apparently within the past few years established itself as a part of the curriculum, the localized character and the youth of the subject have made impossible standardization such as is to be found with some of the other sciences taught in secondary schools. However, out of the discussions and trials and failures and successes certain viewpoints regarding general science are appearing quite definitely:

1. The general science course must not be merely a tandem arrangement of other science courses. As the name implies, general science will draw from any and all sciences for its material; but attempts at giving physiography for a certain number of weeks, biology for another block of time, and so on, will, as demonstrated by experience, usually result in failure.
2. General science must not be specialized according to the interests of the instructor. It happens too frequently that the general science instructor has such an active interest in physics, chemistry, or some other science that the general science course takes on a strong resemblance to one or two specialized sciences.
3. The content of the general science course must be drawn from the life experiences of the pupils. Environment and interest should determine the selection of material; they may well influence the sequence of topics. The organization problem is rather one of making the transitions smooth than of developing a logical course.
4. While logical arrangement is not a necessary characteristic of general science courses, it has been found advisable to group the activities of the course around larger topics, such as air, water, electricity, and the like. Within these larger topics the sub-topics in many courses take the form of problems. A plan by which pupils at the beginning of the year vote upon or otherwise indicate science subjects in which they are interested is entirely workable. Those subjects which the vote indicates are of general interest can then be related to the proper topics. Subjects which can not logically be grouped with larger topics need not be omitted; but they should not be allowed to break the unity of any larger topic.
5. Because of stress laid upon drawing subject material from the environment of the pupil the temptation is ever present to include in general science courses, topics which belong to the social studies field. It may be that future organization will approve this combination. The course here outlined, however, does not contemplate a consolidation of science and social studies.

6. The use of a basal textbook and laboratory manual is advisable. Some teachers of experience prefer to use textbooks only for reference and to organize their own laboratory exercises. The teacher whose course is not developed in its details will do well to use a basal text. Care should be taken, however, that teacher and class do not become slaves to any one textbook. General science texts differ widely in their treatment of various subjects, and the use of reference texts is probably more necessary here than with any other subject in science.

Specific Aims with General Science

The general relation of science to the objectives of secondary education has been discussed in Part I of this manual. Among the more immediate results which pupils should attain through general science courses may be mentioned the following:

1. Familiarity with the underlying principles of scientific method, especially as related to laboratory work. This objective includes manipulation of apparatus, use of correct names for scientific equipment, and the drawing of valid conclusions from experimental data.
2. The gathering of a considerable store of scintific information explanatory of environment and useful to health, vocation, and home membership.
3. Sufficient acquaintance with the material of science to make possible intelligent choice among specialized sciences offered as electives later in the course.

Plan of the State Course

It is evident that difficulties will be encountered in preparing a syllabus for a subject such as general science in which experimentation is rife and in which local environment and pupil interest play such predominant parts. In the following pages an attempt is made, however, to bring a degree of uniformity into general science courses without stifling individuality or smothering experimentation.

The general plan is that of making two-thirds of the course uniform in its activities and the remaining one-third differentiated. In the uniform part of the course are to be found materials which touch the lives of all pupils in Montana high schools. It is felt that some uniformity is desirable especially in a state where transfer of pupils from one school to another is so frequent as it is in Montana. Opportunity for exercise of individuality and special interests is given in the twelve weeks assigned to the differentiated part of the course.

The Uniform Course

The subjects of the uniform course have been selected on the double basis of pupil interest and adult opinion. Investigations of pupil interests in science have been made at various times. An elaborate study of this nature formed one of the bases for selection of material for Washburne's *Common Science.* The November, 1921, issue of *Monthly Guide for Science Teachers* gives a list of topics indicated by pupils as being of especial interest. *The Educational Research Bulletin* of Ohio State University for January 9, 1924, describes a similar study carried on with eighth grade pupils of Colum-

Selection of Material on Basis of Pupil Interest

bus, Ohio. Results for these investigations have been studied carefully and have formed a real basis for selection of material in the uniform course.

No one will contend that pupil interest should form the only criterion by which the value of material should be judged. The explanations of some of the scientific phenomena asked about by pupils are so difficult as to make introduction in a ninth grade course inadvisable, so elaborate as to make satisfactory answer impossible in the limited time available, so specialized as to turn general science from its "general" purpose. Then, too, there are many subjects of science in which the pupil should be interested and in which frequently he is interested when he recognizes them as capable of scientific explanation.

Selection of Material on Basis of Adult Opinion

Adult viewpoint on selection of material for the present course has been secured, in the first place, from studies of the subjects treated in various texts; such studies are described by Dr. Meister in the November, 1921, issue of the *Monthly Guide for Science Teachers* to which reference has already been made, by Dr. Webb in *Contributions to Education,* No. 4, of George Peabody College for Teachers, and by Ada Weckel in the *General Science Quarterly* for January, 1922.* In the second place, much valuable guidance in the selection of material has been secured from the judgments, sometimes expressed, sometimes indicated in course organization, of a considerable number of Montana general science teachers.

The subjects for recitation and laboratory experimentation selected on these bases for the uniform course are indicated in the following topics. Some minor changes are expected; no teacher should accept the course so literally as not to allow deviations where variation appears desirable. The order of topics here given is, for instance, not a necessary part of the plan; whether it is better to occupy the entire first twenty-four weeks with the uniform course or to distribute its material over the whole year is a question for local decision; pupil interest may and very likely will call for elaboration of some topics; teachers wishing to employ the problem method may wish to alter materially the treatment of subjects. Determination of policies affecting these and similar conditions is left to the judgment of the teacher and class. Recommendation regarding the uniform course is definite, however, in two particulars: first, the material of topics with subtopics here outlined should under no circumstances be omitted; secondly, not much more nor much less than 60 single and 40 double periods should be given to the course here presented. If this time allotment is followed, four weeks of the twenty-four will remain for holidays, reviews, tests and examinations. More detailed suggestions regarding time allotments are to be found with each topic.

Optional Features and Definite Recommendations

Recitation and laboratory work should be carried on concomitantly. While laboratory experiments here indicated will usually be reserved for double periods, some of them can be performed in a single period; some exercises will require more than one double period for completion; a considerable number of shorter classroom demonstrations not specifically mentioned in the syllabus should form an essential part of the course as illustrations of theory presented and of processes and appliances described.

* See also the General Science Quarterly for May, 1928, An Analysis of Textbooks in General Science.

Material of the Uniform Course

I. **The Metric System.** (Two days)

Comparison of English and metric measurements.*

II. **Our Solar System.** (Five days)

Sun. Planets. Moons. Phases of the Moon.* Seasons. Stars and other solar systems. The principal constellations.* Stellar distances. The law of gravitation. The earth. Volcanoes, earthquakes, atmosphere, meteors.

III. **Animal and Plant Life.** (Seven days)

Theory of evolution. Field trip for gathering of plant specimens.* Parts of plants and flowers.* Functions of the various parts. Cell structure.* Osmosis.*

IV. **Human Health.** (Ten days)

Care of teeth, eyes, and ears. Taking cold. Keeping well by exercise, fresh air, rest, sleep, cleanliness, and good food. Foods. Vitamins. Testing foods for carbohydrates, protein, and fat.* Preserving food by wrapping, heating, drying, canning, salting, cold storage.* Molds, yeast. Elementary study of useful and harmful bacteria. Development of bacteria under varying conditions.* Transmission of disease. Vaccination. Disinfectants. Sewage and garbage disposal.

V. **Soils.** (Five days)

Breaking up rock by action of glaciers, plants, and water. Kinds of soil found locally and moisture retaining qualities of each.* Capillarity. Field trip for such study of erosion, sedimentation, drainage, and irrigation as is afforded by the locality.* Importance of forests.

VI. **Water.** (Seven days)

Displacement and buoyancy. Specific gravity. Use of specific gravity bottle and hydrometer.* Water seeking own level.* Springs. Wells. Simple siphon.* City water system. Visit to city water plant.* Water supply, rural and urban. Methods of purifying water.* Relation of pure water to good health.

VII. **Air.** (Seven days)

Reality of air.* Weight of air.* Aeroplane. Atmospheric pressure. Vacuums. Action of lift and force pumps.* The mercurial barometer.* Altitude. Effect of pressure on boiling point.* Composition of air. Necessity of air for all plant and animal life.

VIII. **Matter.** (Six days)

Elements, mixtures, compounds.* Physical and chemical change.* Properties and commercial uses of oxygen and carbon dioxide.* Elementary presentation of molecular theory. Acids and bases. Neutralization.*

IX. **Fire.** (Four days)

Oxidation. Burning. Explosions. Drafts. Gas, wood, and coal as

* Items thus marked are suitable for laboratory work.

fuel. Extinguishing fire with water. Quenching fire with chemical fire extinguisher.* (Perform this experiment in the open air.) Fire prevention.

X. **Heat.** (Five days)

Heat requirements of living things. Conduction, convection, and radiation. Charting air currents and heat distribution from stove, fireplace, pipeless furnace, and radiators.* Fireless cooker.* Thermos bottle.* Stove, hot air furnace, hot water, and steam heating systems. Efficiency of various types of heating systems. Study of school heating plant.*

XI. **Heat and Volume.** (Four days)

Three states of matter. Ice, water, steam. Expansion and contraction of solids, liquids, and gases with varying temperatures. Principle of the thermometer. Calibration. Kinds of thermometers. Comparisons of Fahrenheit and Centigrade thermometers with problems involving change from one reading to the other.*

XII. **Air and Moisture.** (Five days)

Evaporation. Humidity. Saturation. Condensation. Relation of temperature and air pressure to evaporation and condensation.* Dew point. Clouds. Winds. Weather forecasting. Study of weather maps.* Manufacture of artificial ice. Refrigeration. Freezing of ice cream.

XIII. **Adhesion and Cohesion.** (One day)

Simple illustrative experiments.*

XIV. **Sound.** (Three days)

Vibration and sound waves. Faintness of sound in a partial vacuum.* The eardrum. Velocity of sound echoes.

XV. **Light.** (Five days)

Reflection of light. The periscope.* Transparency. Velocity of light. Refraction by prisms.* The rainbow. Convex and concave lenses.* The retina and eye glasses. Kodak.* Microscope.* Telescope.* Energy derived from the sun directly and through plants.

XVI. **Magnetism and Electricity.** (Fifteen days)

Study and charting of magnetic field.* Compass. Static, galvanic, and dynamic electricity. Lightning. Dry cell. Storage battery. Electric circuit. Connecting dry cells and lights in series and parallel.* Electro-magnet.* Electric bell.* Telegraph.* Telephone. Buttons, switches, fuses, circuit breakers. Electric light. Elements of electric wiring.* Visit to local electric light plant. Explanation and demonstration of electric home appliances depending upon heat from current: flatiron, grill, toaster, curling iron, electric range, warming pad, etc.* Fundamental principle of induced currents.* Electric home conveniences depending upon motor: washing machine, electric sewing machine, electric refrigerator, vacuum cleaner, electric fan, etc.*

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* Items thus marked are suitable for laboratory work.

XVII. **Simple Machines.** (Three days)

Levers.* Fixed and movable pulleys.* Inclined Plane.* Mechanical advantage. Footpound.

XVIII. **Engines.** (Two days)

Steam engine.* Four-cycle gasoline engine.*

XIX. **The Automobile.** (Four days)

Carburetor.* Timer and distributor.* Transmission gears.* Differential gears.*

Material of the Differentiated Course

No Syllabus Attempted

Obviously it is impossible to outline with any detail the topics of the differentiated course. Attempt to do so would defeat the purposes with differentiation. The topics selected and the treatment within topics should in this part of the course closely fit the conditions of the different schools and communities. Only general considerations for guidance can be given.

Treatment in Detail

It is recommended that topics in the differentiated course be treated much more in detail than in the uniform course. The chief purpose in the uniform course has been to introduce briefly those manifestations of science which will inevitably touch the lives of all pupils. The purpose in the differentiated part of the course should be to cover with much more detail those phenomena of science which are characteristic of the local environment.

Types of Courses Suggested

Occasionally it may be found advisable to elaborate one or more of the topics listed in the uniform course, but more generally the differentiated part of the course will concern itself with scientific factors underlying the industries of the people of a given region. Schools located in towns and cities along the Yellowstone and Milk Rivers may with few exceptions well place the emphasis upon the scientific aspects of the growing of sugar beets and manufacture of sugar; as intensive a study as could be made in twelve weeks on the raising of wheat, corn, peas, apples, cattle, or sheep would seem to be appropriate to much of the plains region and some of our mountain valleys; hydro-electric power has enough scientific mysteries to keep classes interested and occupied in localities where water power is harnessed and electrified railroads operate; railroad shops and steam engineering offer reason for study in the twenty-odd railway division points of the state; twelve weeks is all too short a time to give to consideration of mining, coal, metallic ores, and smelting in our mining regions; oil geology and oil refining call for study in some regions but not in every place where wells have been spudded in; a number of towns in the western part of the state are supported almost solely by lumbering and thus offer advantages for scientific study of trees, forestry, and fire prevention; the various industrial plants of the larger cities of the state furnish opportunity for study of a wide variety of industrial and manufacturing processes; geological phenomena can be studied profitably in all sections of the state; study of the lives and work of great scientists is vital and interesting for all classes.

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* Items thus marked are suitable for laboratory work.

Field trips should form an essential part of the differentiated course. Since this part of the course deals especially with the material of environment some of the most valuable illustrative and experimental equipment is to be found locally. Before taking pupils on a field trip the instructor should himself be familiar with and should acquaint pupils with material which is likely to be encountered. As an instance, the plan of explaining the process of manufacture in anticipation of a field trip to an industrial plant is highly commendable. It is well that pupils be required to write up their observations after their return and some part of the science period of the following day should be reserved for questions and discussions regarding observations made. Unless field trips are carefully planned and reports on results required they are likely to degenerate into purposeless excursions which have little or no educational value. Whenever such tendency should become evident it would be better to send smaller committees of the class on field trips with responsibility for a detailed report to the group at some later time. The bringing of materials to the classroom is preferable to a field trip whenever this alternative is practicable.

Field Trips

Laboratory Apparatus

Laboratory apparatus needed is entirely dependent upon the activities of the course. In the following pages are given five lists of laboratory apparatus:

- **List A.** Apparatus Necessary for Teaching the Uniform Course.
- **List B.** Materials Which May Usually Be Borrowed or Secured by Donation Locally.
- **List C.** Substitutions Which May Be Made for Listed Apparatus.
- **List D.** Apparatus Which May Be Constructed.
- **List E.** Additional Desirable Apparatus.

A sixth list should be added by individual schools, namely, a list of apparatus necessary for teaching the differentiated part of the course. Variable factors such as type of course and amount of equipment locally available make it impossible to prepare such a list for a state course of study.

List A—Apparatus Necessary for Teaching the Uniform Course

The apparatus of List A will be found sufficient for teaching the material of the uniform course provided alternation of experiments and of work within experiments is carried out whenever possible. Occasionally a teacher may wish to arrive at a given laboratory result by an experiment somewhat different from the one here contemplated. Such variation in laboratory work will call for corresponding change in apparatus needed, but will not appreciably lower the cost of materials.

Some of the material may be bought locally; the greater part of the apparatus will have to be secured from a company dealing in laboratory apparatus. The cost of List A may be considerably lightened by making use of articles borrowed, donated, substituted, or constructed. As previously mentioned, Lists B, C, and D enumerate such materials. If the local community is drawn upon for considerable of this equipment, the cost of apparatus for the differentiated course should not be prohibitive.

If more than one science is taught in the same laboratory it is not necessary to duplicate any of the items which are available for any of the other sciences included in this list, other than duplicates for individual or group experiments.

Note: The number in the parentheses immediately following the description indicates the maximum number of pupils who may be served by the given amount of apparatus.

List A—General Apparatus

Quantity Recommended	Description	Approximate Price
1	**File,** triangular, 4"	$ .15
1	**One-Liter Measure** (4)	.75
1	**Measure,** liquid, tin, with lip, 1 qt. (4)	.25
1	**Meter Stick,** graduated to both mm and ⅛" (4)	.35
3	**Lever Knife-Edge Clamps,** for meter stick (8)	1.05
2	**Triple Pulleys,** bakelite, each pulley 5 cm in dia. (8)	1.30
1	**Lift Pump,** working model of glass, 37 cm long	1.50
1	**Force Pump,** working model of glass, 37 cm long	1.50
1	**Hydrometer,** for light liquids, 30 cm long (8)	.70
1	**Specific Gravity Bottle,** capacity 25 cc (8)	.65
1	**Battery Jar,** 7" high, 5" dia., (4)	.65
1	**Barometer Tube with Stopcock** or Boyle's Law Tube	2.50
1	**Vacuum Wax,** 4 oz. jar	.25
1	**Air Pump,** exhaust and compression	4.50
1	**Air Pump Plate,** lathe-turned surface, 21 cm dia.	6.00
1	**Bell Jar,** straight form, glass stoppered, 1 gal.	3.50
1	**Rubber Balloon,** large	.85
1	**Steam Engine Model,** locomotive type, large size, complete model (or 1 No. 1772 Locomotive Chart, Midako type, 12"x40"-40c)	6.00
1	**Soft Iron Rod,** round, 15x1.2 cm (4)	.15
1	**Bar Magnet,** rectangular, polished steel, 15x1.9x0.7 cm (2)	.35
1x1 lb.	**Iron Metal Filings,** finely prepared	.25
1	**Magnetic Needle, mounted,** 15 cm long	.65
1	**Compass,** 25 mm dia. (4)	.25
4	**Dry Cells** (dry batteries), standard size, 1.5 volts, 25 amperes on short circuit	2.00
1	**Incandescent Lamp,** carbon filament, 110 volts, 16 candle power, 50 watts (8)	.40
1	**Telegraph Key**	2.75
1	**Telegraph Sounder,** Standard Commercial form. Resistance 5 ohms	3.00
1	**Bell,** electric, dia, of bell 2½" (8)	.75
1	**Push Button,** stamped metal, bronze finish (4)	.18
1	**Receptacle,** porcelain base (8)	.85
1	**Prism,** equilateral, 25x75 mm (2)	.75
1	**Balance,** Harvard trip, agate bearings, beam weighs 10 g to 0.1 g, sensibility 5 cg	12.00
1	**Spring Balance,** double scale, capacity 64 oz. in 1 oz. div and 2000 g in 25 g div. (8)	.85
1 set	**Weights,** brass, in wood block, 1 g to 500 g, including 1 g, (2)2 g, 5 g, 10 g, (2)20 g, 50 g, 100 g, (2)200 g, and 500 g	5.25
1 set	**Weights,** Universal, with hooks, 10 g to 1 kg, including 10 g, (2)20 g, 50 g, 100 g, (2)200g, 500 g, and 1 kg	3.75
1	**Condenser,** Liebig's, glass, 400 mm long	1.20
1	**Beaker,** Pyrex, with lip, capacity 400 cc (2) net	.30
1	**Bottle,** wide-mouth, size 4 oz. (2)	.15
1	**Bottle,** wide-mouth, size 8 oz. (2)	.20
1	**Bunsen Burner,** simple form (2)	.35
2	**Clamps,** burette, with rubber covered jaws	1.20
1	**Clamps,** screw compressor (4)	.25
1	**Clamp,** Stoddard's test tube (2)	.14
2	**Clamps,** Mohr's, brass, for burettes, 2¾" (8)	44
1 pkg.	**Corks,** quality XX, assorted, 1 gross, Nos. 0 to 11	.65
1	**Dish,** evaporating, Coors porcelain, No. 00A, capacity 70 cc (2) net	.12

1 pkg.	**Filter Paper**, 100 sheets, 10 cm dia.	.14
1	**Flask**, Pyrex, flat bottom, 500 cc capacity (4) net	.30
2	**Forceps**, steel, 5" long (8)	.30
2	**Funnels**, glass, 100 mm dia.	1.00
1	**Funnel Tube**, thistle top, straight stem, 30 cm long (4)	.15
1	**Gauze**, iron wire, 20 mesh, 5"x5" (2)	.10
1	**Glass Plate**, square, 4"x4" (2)	.06
1 lb.	**Glass Tubing**, outside dia. 6.5 mm (12)	.70
1	**Graduate**, cylindrical, graduated up and down, 100 cc by 1 cc	.80
3	**Rubber Stoppers**, 1-hole, 1 each Nos. 3, 5, and 8 (4)	.40
3	**Rubber Stoppers**, 2-hole, 1 each Nos. 3, 5, and 8 (4)	.40
3 ft.	**Rubber Tubing**, white, $\frac{3}{16}$" dia. $\frac{3}{64}$" wall (2)	.36
1	**Support**, ring stand, with 3 rings (4)	1.50
1	**Support**, test tube, 6 tube (4)	.60
12	**Test Tubes**, 6"x¾" (4)	.35
1	**Thermometer**, engraved double scale, -10° to 110° C and 10° to 220° F, 12" (8)	2.00
1	**Trough**, pneumatic, galvanized iron, inclined sides, with nest, 4"x7"x10" (4)	.85
12	**Chimneys**, student's lamp (4)	.35
1 lb.	**Annunciator Wire**, copper, D.C.C., No. 18	.70
1 spool	**Copper Magnet Wire**, No. 24, D.C.C. (4-oz. spool)	.55
10 ft.	**Fuse Wire**, 1 ampere	.10
10 ft.	**Fuse Wire**, 5 amperes	.20
8 ft.	**Gutta Percha Covered Copper Wire**, No. 14 (4)	.40
1	**Tripod Magnifier**, double lens, wide field	.80
1 env.	**Weather Maps**, 100 in env., 7¾"x9¾" net	.70
1	**Yard Stick**, hard maple (4) (B)	.15
1x4 oz.	**Nichrome Wire**, No. 24	1.75
*1x6 lbs.	**Acid Hydrochloric** Technical Concentrated	1.05
*1x1 lb.	**Acid Nitric** Technical Concentrated	.65
*1x1 lb.	**Acid Sulphuric** Technical Concentrated	.55
*1x1 lb.	**Ammonium Hydroxide** Technical Concentrated	.45
*1x1 lb.	**Ammonium Nitrate** Pure Granular	.50
1x1 lb.	**Calcium Carbonate** Marble Chips	.20
1x1 lb.	**Carbon Tetrachloride** Pure	.35
1x4 oz.	**Fehling's Solution A**	.25
1x4 oz.	**Fehling's Solution B**	.30
1x1 lb.	**Iodine Solution** in Potassium Iodide and Water	1.00
1x1 lb.	**Limewater** (Calcium Hydroxide Solution)	.35
2x1 lb.	**Mercury Metal** Virgin Grade (Quicksilver)	5.50
*1x1 lb.	**Sodium Hydroxide** Technical Granular	.25
*1x1 lb.	**Sodium Peroxide** C.P.Powder	1.00
1 vial	**Test Paper** Litmus blue	.10
1 vial	**Test Paper** Litmus red	.10
	Various food stuffs containing carbohydrates, protein, and fat.	
1	**Weather Map** (2) Procure from local office of Weather Bureau or from Weather Bureau, U. S. Dept. of Agriculture, Washington, D. C.	
	Total for General Apparatus	$99.94

* Chemicals marked (*) cannot be sent by parcel post.

List B—Materials Which May Usually Be Borrowed or Secured by Donation Locally

The gathering of materials available locally for the general science laboratory should not end with this list. A large number of articles of scientific interest will cheerfully be loaned or donated by stores, telephone offices, repair shops, garages, car owners, and homes. Pupils should be encouraged to bring articles from their homes. Not infrequently the most useful laboratory materials of this kind are those which have outlived their practical usefulness and consequently can be taken apart. Burnt out electric light bulbs can be used for demonstrating bouyancy and air pressure, empty varnish cans for air pressure and convection, broken thermos bottles for various methods of transmission of heat, a discarded electric fan motor for construction of motors, and so on. It is desirable that as soon as possible the science laboratory secure equipment of its own instead of borrowing articles from members of the community. The securing of articles by donation should never be discontinued.

Triangular Files
Yard Sticks
Quart Measures or Jars
Food Stuffs
Hydrometers
Old Kitchen Lift Pump
Alarm Clock
Microscope
Light Receptacles
Fuse Receptacles and
Burnt Out Plugs
Burnt Out Electric Light Bulbs
Kerosene Lamp
Thermos Bottle
Fire Extinguisher
Telescope or Field Glasses
Reading Glasses
A Kodak
Storage Battery
Electric Bells
Telephone Transmitter
Telephone Receiver
Curling Iron
Warming Pad
Electric Toaster
Electric Grill
Percolator
Electric Iron
Vacuum Cleaner
Electric Sewing Machine
Electric Cake Beater
Electric Fan
Block and Tackle
Automobile Jack Screw
Automobile Engine Model
Spark Plugs
Carbureter
Timer Model
Automobile Ammeter
Transmission Gears Model
Differential Model
Vaseline
Candles
Wood Tapers
Empty Varnish Cans
Milk and Pickle Bottles
Wrapping Paper
Cord and Thread
Darning Needles
Knife
Scissors
Scientific Toys of Various Kinds (Mechano, Erector, Chemocraft, The Gilbert Sets, St. John Sets, Etc.)

List C—Substitutions Which May Be Made for Listed Apparatus

It must not be supposed that articles here listed are superior to those for which they are substituted; quite the contrary is true as a general rule. The list of substitutions may help point a way for temporary relief of an understocked laboratory.

Apparatus	*Substitute*
Bunsen Burners	4 oz. Alcohol Lamps or Gasoline Blast Lamps
Pyrex Beakers	Glass Tumblers
Gas Collecting Bottles	Milk or Pickle Bottles
Evaporating Dishes	Low Tin Pans or Tin Covers 3½ or more inches in diameter
Plate Glass	Window Glass
Battery Jars	Mason Jars
Pneumatic Trough	Baking Pan and Bricks
Rubber Balloon	Toy Balloon, Football, or Basketball Bladder
Bar Magnets	Magnetized Files

List D—Apparatus Which May Be Constructed

A great deal of apparatus may be improvised by an ingenious instructor and his class. Such construction, however, is too frequently done at the expense of much valuable time which could be put to better advantage were the apparatus purchased. Another difficulty with improvised apparatus is that usually only one piece is constructed for the whole class; generally speaking an experiment for which the apparatus is constructed becomes then and there a demonstration experiment. Exception to this statement is to be noted where the apparatus is quickly and easily made with such experiments as water seeks its own level, the siphon, and the electro magnet. Some experiments such as osmosis and distillation of water for which apparatus is set up are quite properly, although by no means necessarily, of the demonstration type.

It is recommended that construction of apparatus be with infrequent exceptions limited to individual or small group project work. Constructing devices or models of them serves to acquaint the pupil with the underlying scientific principles; and if the pieces of apparatus thus constructed are preserved from year to year they soon make an interesting laboratory display which may be used for supplementing regular laboratory equipment.

Description of much improvised apparatus may be found in the various textbooks and in such books as Woodhull's "Home-Made Apparatus" (Barnes); Good's "Laboratory Projects in Physics" (Macmillan); Downing's "Field and Laboratory Guides in Biologicl and Physical Nature Study" (University of Chicago Press). "The Monthly Guide for Science Teachers" and its successor "The Science Classroom" (Popular Science Monthly Publishing Company) have a section each month given to description of apparatus any pupil or teacher can make.

Among pieces of scientific apparatus which may be constructed with glass tubing, rubber tubing, T and U tubes, test tubes, wide mouth bottles or milk bottles, rubber stoppers of various kinds and sizes, lead shot, paraffin, some wooden boxes, etc., together with a few tools are the following:

Test Tube Racks
Specific Gravity Bottle
Hydrometer
Stability Toys
Cartesian Diver
Lift Pump
Self Starting Siphon
Water Cooler
Model of City Water System
Model of Steam Heating System
Model of Hot Water Heating System
Action of Geyser
Air Thermometer
Wet and Dry Bulb Thermometer
Fire Extinguisher
Convection Current Apparatus
Fireless Cooker
Iceless (Evaporating) Refrigerator
Pin Hole Camera
Periscope
Electric Water Heater
Telegraph Key
Arc Light
Various Kinds of Levers

List E—Additional Desirable Apparatus

The greater number of articles in List E may be borrowed from the laboratories provided for other sciences. In two-year high schools where general science is the only science subject taught List E should not be an object of concern until all apparatus of List A is secured. Even then the first purchases should be designed to add more pieces of each kind in order that work of the pupils may become more individualized. After the general science laboratory is so well supplied with equipment as to allow pupils to work by two's in nearly all experiments, the following equipment may be secured:

Quantity Recommended	Description	Approximate Price
1	**Metric Chart,** mounted on plain rollers, 25″x41″	$ 2.25
1	**Capillary Tubes Apparatus,** set of 7, mounted in frame	1.25
1	**Diffusion of Gases Apparatus,** double-bottle type	.60
1	**Osmose Apparatus,** simple form, including jar, clamp, and double-ended thistle tube with membrane	2.50
1	**Inclined Plane,** all metal form	7.75
1	**Universal Sun Dial,** unmounted, for use in 40° latitudes	6.50
1	**Siphon,** arms 20 cm and 30 cm long	.30
1	**Aneroid Barometer,** metric and English scales, for altitudes up to 3,500′ (For high altitudes a special barometer is needed)	10.00
1	**Bell-in-Vacuo,** with bell jar and suspended ball	4.50
1	**Air Thermometer Bulb,** 5 cm dia., stem 30 cm long	.20
1	**Conductivity of Water Apparatus,** funnel 12 cm dia	1.00
1	**Ball and Ring,** to show expansion due to heat	1.50
1	**Unequal Expansion Bar,** 30 cm long	.75
1	**Calorimeter,** drawn polished aluminum, 12.5 cm high, 7 cm dia.	.85
1	**Dipping Needle,** 8 cm, mounted with graduated arc	3.50
1	**Electrolysis Apparatus,** length over all 40 cm	5.00
1	**St. Louis Motor,** all metal base, spring clip magnet holders, flat adjustable copper brushes	3.50
1	**Electromagnet Attachment for St. Louis Motor,** essential for complete dynamo demonstrations	1.25
1	**Lamp-Board Rheostat,** without lamps	16.00
1	**Switch, knife,** double pole, single throw, 15 amps.	.55
1	**D'Arsonval Galvanometer,** all metal frame, tripod with leveling screws	6.25
1	**Volt-Ammeter,** D. C., full 5″ scale, range 10 volts and 10 amperes in 0.1 volt div.	18.00

1 set	**Demonstration Lenses,** 38 mm dia., set of 6	1.75
1	**Sextant,** mounted, complete	8.50
1 set	**Cork Borers,** brass, set of 6	1.00
1	**Graduate,** cone shape, metric and English graduations, 8 oz., 250 cc	1.50
1	**Sun Path Dial**	.40
1	**Washington School Collection of Rocks and Minerals,** including 20 rocks and 20 minerals, all labled in compact display case ....net	6.50
4	**Dishes,** petri, double culture dish, 80 mm dia.	2.00
1 set	**Microscope Slides,** for General Science, special set of 25 ....net	8.50
1	**Microscope,** compound, 2 eyepieces, 2 objectives, double circular nosepiece, magnifications of 50, 100, 215, and 430 diameters	74.50
1 set	**W. & A. K. Johnston's Physiology Charts,** set of 8, with solid chart head and tripod stand	8.50
1	**Tellurian,** complete with manual	42.00
4 tubes	**Agar Culture Media**	1.60
	Total for Additional Desirable Apparatus	$250.75

PART III. BIOLOGY

Fundamental Principles

Biology and Related Sciences

The syllabus presented herewith is for biology only. There is, however, no intention of causing abandonment of botany, zoology, physiology, hygiene, and sanitation as high school sciences. The situation in state and nation at the present time is that biology has in the large majority of high schools displaced or rather absorbed these other sciences. Furthermore, those schools which continue teaching such special sciences usually have exceptionally well-qualified specialists as instructors in these subjects. For these and other reasons it is thought unnecessary to prepare state courses of study for them.

Objectives

The study of biology connects up very definitely with some of the N. E. A. objectives discussed in Part I of this course of study:

1. Health. Through analogy and direct application of principles learned, health as an objective finds realization more definitely in biological science than in any other school subject except physical education.

2. Home membership and citizenship. It may be that home membership and good citizenship objectives are too greatly stressed in some general biology courses, but such topics as conservation of natural resources, protection of game and birds, eradication of plant and animal pests, and prevention of spread of contagious disease have a distinct home and citizenship flavor as well as a biological one.

3. Leisure. Appreciation of nature through acquaintance with birds, flowers, trees, and numerous other forms of plant and animal life provides not only a means but also a motive for worthy employment of leisure time.

4. Ethical character. Respect for life is a result of biology study directly assignable to the ethical character objective.

A Natural Science

Biology probably more than any other science offers opportunity for the particular bent of the instructor or textbook to take a class on physical and mental excursions which are undoubtedly delightful and interesting, which may be made to appear most useful, but which are, nevertheless, by-paths and not main traveled roads of science. So long as biology is classed as a natural science it seems to be the judgment of the best informed instructors that considerable observation and experimentation relating to animals and plants should be performed. The achievement of special aims with regard to economic values, social phases, appreciation of nature, agriculture, sex information, or even so important a subject as human hygiene should be related to and secure foundation in scientific knowledge of plants and animals. The biology course exists for the purpose of introducing pupils to fundamental biological phenomena; no matter how desirable these economic, social, appreciative, rural, sex, and hygiene viewpoints may appear, they must not be allowed to crowd out the natural science part of the course.

The very name *biology* suggests study of living, not dead, materials. In order to learn some of the facts regarding structure it is necessary to dissect, to cut cross-sections, to preserve in formaldehyde, and so on; more time should, however, be spent with living organisms than with dead ones.

Study of Living Specimens

The use of local and seasonal materials rather than specimens shipped from afar is one indication that the principle of working with living things is being followed. Fall and spring study, especially, should concern itself with the out-of-doors. The biology instructor of more than average ability will not only be able to take his class on excursions without upsetting the school program or demoralizing discipline in his own and other classes, but will also instill into students an interest and fondness for spending time in the open outside of school hours. Thus are brought to the biology recitation and laboratory many questions, observations, and specimens which otherwise would not be included.

Many of the materials studied, particularly during the winter months, should be developed in the biology laboratory. This requires some forward looking planning on the part of the instructor; it means keeping things sprouting to take the places of others which have completed their cycles. Living specimens should be found in jars, boxes, flower pots, acquariums, and vivariums at all seasons of the year. By these and similar means the biology laboratory may be made a depository mainly for living things instead of for dead and pickled remains.

Macroscopic Work Recommended

An elementary biology course should concern itself with macroscopic rather than with microscopic work. Entirely aside from the high expense of supplying the class with a considerable number of compound microscopes, it may be said that the time spent with teaching microscopical technique to the novice can, it seems, be put to better advantage in the first year of biology work. The need for use of compound microscopes is not very frequent in an elementary course, and practically may be met by microscopic demonstrations given from time to time by the instructor. Sometimes drawings and diagrams may be made to take the place of considerable microscopic work. Much of such microscopic work as is necessary may be done with small magnifiers supplied to pupils.

Miscellaneous Considerations

General recommendations regarding groups for experimentation, field trips, notebooks, reference books, visual instruction, projects, and sources of material are given in Part I of this manual. Following are brief comments on some of these same subjects as related to biology:

1. Laboratory groups. Much of the work, especially on structural phases, can be made individual in biology. When microscopic work is done, except with compound microscope demonstrations, not more than two pupils should work together. Special projects usually will enlist larger numbers in groups.
2. Field trips. Biology field trips should whenever possible follow class study. Give pupils in advance a list of what they are to find. It is well to give points for success in finding specimens asked for and extra credit for discovery of pertinent material not listed. Pupils should be encouraged to make notes on where various plans and

animal specimens are found and under what conditions they develop and flourish. Recognition of types and making of collections and drawings ought to be stressed on field trips. Following are field trips listed by members of the committee co-operating in producing this manual; more than one trip is advisable and necessary with some of the subjects listed: 1. Collection of specimens for laboratory study. 2. Flowers. 3. Insect homes and habits. 4. Leaves and adaptations. 5. Fruits and seeds. 6. Trees and shrubs. 7. Fungi and lichens. 8. Life in a brook. 9. Birds.

3. Notebooks. Drawings are features of biology notebooks. To aid in this work pupils should be supplied with high quality drawing paper, with a 4H pencil, and with a pad of fine emery cloth for producing a sharp point on the pencil. Artistic ability is desirable but not necessary; artistically considered, tracing drawings in ink may be satisfying, but biologically contemplated, such application is a waste of time. Some uniform system of labeling is recommended. Drawings should be fairly large; considerable gain in clearness and neatness is made if compliance with this rule is insisted upon from the beginning. Above everything else, drawings must be accurate sketches of things seen; they should not be copies of other drawings from blackboard, chart, or textbook.

4. Reference books. In addition to reference books listed in Part I of this syllabus, reference is made to the *Library Manual for Montana High Schools,* pages 18-19, for recommended books on biology, botany, and zoology. In ordering reference books it is well to bear in mind that money is much more profitably expended if a number of copies of the same book is secured than if a large variety of single copies is provided.

5. Sources of material and special help. The State Board of Health, State Capitol, Helena, will be glad to supply samples of blood, bacteria plates, and considerable literature relating to facts of health and disease, especially to social hygiene. The Departments of Botany and Zoology at the State University, Missoula, offer special aid to high school biology classes in the matter of identifying specimens, advising regarding vocational opportunities in biology, giving addresses on botanical subjects, aiding in securing special materials for study, and in such other ways as may be possible. The Department of Botany and Bacteriology, Montana State College, Bozeman, is ready to co-operate with high school biology departments; special mention should be made of Riker Mounts on weeds, stock poisoning plants, and plant diseases which will be loaned, provided high schools will pay transportation charges; additional help in presenting agricultural phases of biology may be secured from this source. Commercial companies dealing in biological supplies are listed in Part I.

The Uniform Course

Plan of the Course

The material of the uniform course here, as with general science, is expected to occupy two-thirds of the school year. The remaining third of the year is reserved for differentiation; consequently the general comments found under the headings *Plan of the State Course* and *Optional Features and Definite Recommendations* in Part II apply to biology with equal force.

Order of Topics

The order of topics is suggestive merely and may be altered to suit conditions. Teachers who for good reason desire to follow some other sequence should not feel obliged to adhere to the order of topics here given. It must be borne in mind, however, that in Montana the springtime during the school session is quite restricted; consequently much of the material which in sections farther south may claim attention toward the close of the school year in this state may be studied to better advantage in the fall. The only satisfactory alternative to such seasonal arrangement is to grow a great number of plants in the laboratory.

Material of the Uniform Course

I. Introduction. (Four days)

A good introduction to biology consists in collecting specimens for the laboratory. Much of the plant material to be used later in the year can best be collected in the fall and stored. Such animal specimens as are collected for later use and cannot be kept alive may be preserved in formaldehyde. Observation of these plants and animals in their natural environment and fresh state needs to be stressed at the time of collection and recalled when the forms later are taken up for detailed study. A beginning with observation and identification of birds and flowers should be made at this point. Brief study of aims and principles of biological study may be introduced if desired. In addition, review of physical and chemical changes as studied in general science forms a desirable starting point.

II. Flowers. (Nine days)

Minimum Topics: Parts of a flower and functions of each part. Adaptations of various kinds. Pollination. Training for recognition of individual flowers.

Discussion: A considerable variety of flowers should be secured from fields and gardens and studied structurally. Types should include: complete, perfect, composite, regular and irregular flowers. With such variations as the locality and the season may afford selection is recommended from the following specimens: nasturtium, geranium, pansy, sweet pea, lily, mustard, apple blossom, tulip, cosmos, daisy, dandelion, wild aster, bull thistle. Have pupils place drawings of flowers and diagrams of parts in their notebooks. Study self-pollination and cross-pollination, adaptations of flowers for the protection and distribution of pollen, fertilization of the ovule. For laboratory study of germination pollen grains may be sprouted in a weak sugar solution. Study of individual flowers, especially

identification, should be carried on whenever feasible throughout the year.* Observation of spring flowers should under no conditions be omitted regardless of the time of year when the more special study of flowers takes place. By the end of the year the pupils should be able to identify at least twenty different varieties of local flowers. The May, 1927, issue of the National Geographic Magazine contains excellent colored plates of Western flowers.

III. Insects. (Ten days)

Minimum Topics. Number and variety. Brief classification. Structure and functions of insect organs in general; special laboratory study of selected types. Economic values. Losses due to insects.

Discussion: Insects are most easily studied in the fall or spring of the year; in the sequence here planned this study comes in early fall. The break thus occasioned in logical study sequence of plants may be made less objectionable if pollination in flowers is taken up as the last subject in that topic and the part which insects play as distributors of pollen be the first subject treated in the present topic.

Encourage collection and classification outside of the school hours. Secure as large a collection of insects as can conveniently be kept in insect cages and terrariums constructed by the pupils. at some time during the year observe the development of the fly in exposed meat, of the mosquito larva kept in glasses, of the caterpillar spinning his cocoon, and of as many as possible other insects. Pick some few types for special study. In Montana schools the grasshopper is probably most frequently selected for complete study in the laboratory. For variety and comparison it is advisable to introduce a special study of other insects or, at least of certain parts of other insects; antennae and scales of moth and butterfly, legs of the bee, feet and wings of fly and mosquito are illustrations in point.

The treatment of insect pests will vary with different localities. Aside from those species mentioned above, some of which are harmful, selection from the following list is suggested: Potato bug, army worm, wire worm, tent caterpillar, coddling moth, gypsy moth, chinch bug, tick, and cockroach. The good done by insects should be given some attention as should the destruction of injurious insects by other insects and by birds. Reports of the State Entomologist, Montana State College, Bozeman, should be studied in connection with this topic.

IV. Leaves. (Seven days)

Minimum Topics: Structure. Transpiration. Photo-synthesis.

Discussion: Study gross structure of at least five different kinds of leaves. Give attention to veining and to simple, compound, and modified leaves. Have pupils introduce drawings of leaves in notebooks. A microscopic demonstration by the instructor showing

* See topic No. XIII, "Birds" for a similar suggestion.

stomata, palisade layer, spongy tissue, and structure of veins may follow; choose large, succulent leaves for demonstration. Experiments should be performed showing (1) loss of weight through transpiration, (2) presence of both sunlight and air necessary for manufacture of starch, (3) oxygen given off during the process of starch-making. Extract chlorophyll with alcohol. Explain the oxygen-carbon cycle. No experimentation is advised on manufacture of protein and oil by plants.

V. **Stems.** (Five days)

Minimum Topics: Structure of mono-and dicotyledonous stems. Circulation in stems. Economic values.

Discussion: Select at least one mono- and one dicotyledonous stem for study. Choose local specimens, such as weeds, corn, sunflower, trees, and vegetables. Study external appearance of dicotyledonous stems and both cross- and longitudinal sections of monocotyledons and dicotyledons. Further microscopic work on cells may be done at this point. Stress osmosis, capillary attraction, root pressure, and transpiration in relation to circulation. Trace course of a liquid up a stem by putting eosin in water and observing the rise of the colored liquid in roots, stems, and leaves of some plant. Have members of class list and identify local trees. Limit study of economic values to wood and potatoes.

VI. **Fruits and Seeds.** (Seven days)

Minimum Topics: Structure of monocotyledons and dicotyledons. Germination. Influence of gravity, light, temperature, moisture, air, and soil upon growth. Adaptations for dispersal of seeds. Economic values.

Discussion: Study, learn parts, and represent in four-inch drawings the structure of four or more dicots and monocots. The following (numerous variations may be introduced) are suggested as desirable for structural study: bean, pea, squash, corn, wheat, sunflower, castor bean, various kinds of garden and orchard fruit. Review general science work by testing seeds and fruits for nutrients. Plant seeds and study stages in germination. Plant radish seeds in sponge to show effects of gravity and moisture. Observe development of plants grown under varying conditions of light, temperature, air, moisture, and soil. Emphasize food storage and digestion. Treatment of economic values and adaptations for dispersal of seeds should be brief.

VII. **Roots.** (Five days)

Minimum Topics: Parts and functions of roots. Osmosis. Root cells. Economic values.

Discussion: Grow roots from radish seeds or wheat by planting in a pocket germinator, between pieces of wet blotting paper in a saucer, or in water soaked cotton. Give especial attention to primary root, root hairs, and root tips. At this point give compound microscope demonstration on cell structure and protoplasm.

Protoplasm may be observed in the root tip of wandering jew. Bring observation of pupils to bear on some large roots of trees, corn, and vegetables. Study also roots of clover. Two experiments in osmosis should be performed: (1) egg osmosis; (2) osmosis demonstration with thistle tubes showing that a sugar solution will pass through animal or vegetable membranes whereas starch will not. Part of the study of osmosis will be review of work done in general science. The significance of osmosis in living things should be stressed. Give brief discussion to nutrients contained in roots and consequent economic values.

VIII. **Fungi.** (Three days)

Minimum Topics: Molds. Yeast.

Discussion: One or more microscopic demonstrations should be given by the instructor. Secure specimens from the household, the garden, the farm, and the forest. Grow bread mold and observe it in its various stages. Show the formation of carbon dioxide with yeast.

IX. **Bacteria.** (Seven days)

Minimum Topics: Sizes and shapes. Increase of bacteria under varying conditions. Bacteria and food. Bacteria and disease. Values of bacteria.

Discussion: Review work done on this subject in general science. Prepare agar cultures and study results after inoculation with bacteria from teeth, pencil point, fly dust, hands, air in schoolroom, etc. Note also growth of bacteria colonies under varying conditions of temperature, light, and moisture. A microscopic demonstration of bacteria should be given by the instructor. Study bacteria in milk, broth, meat, and water which has been standing. Demonstrate preservation of foods. Counteract the idea that all bacteria are harmful by stressing values as well as losses from bacteria of decay and by indicating other valuable bacteria such as nitrogen-fixing bacteria; of over 600 bacteria types recorded about 60 are disease producers. Discuss transmission of "germ" diseases and prevention or control by immunization, sanitation, and disinfection.

X. **Protozoa.** (Two days)

Minimum Topics: Paramecium. Protozoa as food. Protozoa and disease.

Discussion: Prepare hay infusion and give microscopic demonstration of paramecium; stain with dye to make parts clearer. Observe reproduction by fission. Study also amoeba and vorticelli if available. Discuss protozoa and disease and protozoa as food.

XI. **Fishes and Frogs. Mammals. Relation to Human Biology.** (Thirty-five days)

Minimum Topics: Observation of live fishes and frogs. Life history of frog. Complete dissection of fish or frog. Relation of vital organs and life processes of fish, frog, and larger animals to those of human beings.

Discussion: Aquaria are essential to study of this subject; simple ones may be constructed. Observe response to stimuli and methods of locomotion and breathing of both fish and frog. Some attention should be given to economic importance of fish and of the fish industry. A fish hatchery should be visited or, if this is impossible, description may be given by some member of the class who has visited one. The development of egg-tadpole-frog should be noted by direct observation in the laboratory.

Make full dissection of fish or frog; complementary dissection work on both may be substituted. It is usually necessary to purchase the specimens for such work. Considerable time need be given to this part of the course since the pupil should secure a fairly complete knowledge of the following systems and processes. Lay particular emphasis upon relation to human biology:

1. The alimentary canal—parts, enzymes, digestion, absorption. Perform experiment of changing starch into grape sugar by action of saliva or diastase. Lay especial stress upon corresponding organs and processes of the alimentary canal in human beings.
2. The nervous system—divisions and functions. Compare with cerebro - spinal systems (studied directly, through charts, or through textbook illustrations) of larger animals. Secure and dissect eye and ear of pig or some larger animal. Lead to study of structure and functions of parts in human nervous system.
3. The blood — characteristics and circulation. Test blood for nutrients. Show clot and use of fibrin. Give microscopic demonstration of fresh blood, but do not enter into much discussion of composition of blood. Observe circulation in tadpoles. Dissect heart of calf or some larger animal. Study from diagrams, charts, or textbook illustrations the circulatory system in human beings.
4. The respiratory system—organs and action of breathing. Frog's lungs may be used as a basis but some time while this subject is under consideration the lungs of some larger animal should be provided. These may usually be secured from the local butcher; they will remain fresh for one day. Demonstrate action of diaphragm and explain proper method of breathing. Indicate reasons for common diseases of the respiratory organs.
5. The skeleton. Relate to human skeletal arrangement. In general, the study of human anatomy in elementary biology should be confined to such similarities as are brought out in studying lower animals. Probably the most valuable device for giving pupils a general idea of human anatomy is to have the class observe a butcher dissect a hog, sheep, or cow. By this means pupils will secure some real concept of size, location, and functions of vital organs together with understanding of by what means and how firmly these organs are kept in place. Special aids in the form of mannikins, skeletons, and models are expensive but useful in teaching human and lower animal anatomy. Charts cost much less and will, with proper explana-

tions, serve almost as well as models. Illustrations in supplementary textbooks, especially if made available to the whole class through a blackboard diagram or lantern projection, are valuable.

XII. **Hygiene.** (Seven days)

Minimum Topics: How to remain healthy. Disorders and emergencies.

Discussion: Much of the theory of this part of the course will be review of matter studied in physiology and general science. Knowledge and practice of the laws of health should, however, not be taken for granted even at this time.

Hygiene of the mouth needs to be emphasized. The toothbrush habit is by no means universal, and the majority of our pupils probably do not know that the cheapest, least painful, and most effective method for preservation of teeth lies in going to the dentist regularly and with reasonable frequency. More detailed treatment of diet may be introduced here than in earlier courses. Have each pupil keep a record of his diet for a week; check on expense and balance of the diet for this week. Explain importance of exercise in throwing off bodily waste. Discuss biological as well as social importance of cleanliness. With hygiene of the skin may be introduced care of eye and ear. Importance and methods of ventilation need be given attention; too many of our pupils sleep with windows nearly, if not entirely, closed. A term paper on some hygiene topic; such as, public sanitation, personal hygiene, values of different kinds of exercise, fatigue and rest, water supply, food contamination, ptomaines, pasteurization, food preservation, and so forth, is a good device.

It is not recommended that the biology course should take on the appearance of medical study, but some work on common bodily disorders and on important emergency measures should be introduced. Methods of caring for disorders of the food tract, curing of colds, and treatment of cuts, scratches, and burns need attention in the biology course. Boy Scouts will put on excellent demonstrations of tourniquets, resuscitation, and general first-aid work. All pupils should become acquainted with the use of materials contained in a first-aid cabinet. Some knowledge of simple home remedies is useful in emergencies.

XIII. **Birds.** (Five days)

Minimum Topics: Identification of local birds. Values of Birds. Bird dangers and protection.

Discussion: Bird study should be carried on incidentally throughout the year, but especially during fall and spring migrations.

Study both resident and migrant types, their habits, appearance, and adaptations. The most interesting singers, game birds, and birds of prey should be included. The bird life in various Montana localities differs so widely that no list of birds for study is here given. By the end of the year the pupil should be able

to recognize at least twenty types. As aids in identification western bird guides such as those of Bailey and Reed are recommended. A. A. Saunders has issued one book and P. M. Silloway two treatises on Montana birds. Farmers' Bulletin 513 (1913) gives 56 colored plates of birds of farm and orchard; this bulletin may be secured for 15c from the Superintendent of Documents, Washington, D. C. Another important address in connection with material for bird-study is that of the National Association of Audubon Societies, 1974 Broadway, New York City.

Aesthetic and economic values of birds call for some attention. Economic value is probably best approached through discussion of the food of various birds. Many useful birds are killed by persons who believe them to be harmful.

Information needs be given also on how to protect birds from bad weather and from bird and other animal enemies, on how to preserve game birds from extermination by enforcing game laws and by establishing bird reserves, and on how to save birds from starvation by proper feeding during periods in the winter when food is not otherwise obtainable.

XIV. Variation and Mutation. (Four days)

Minimum Topics: The theory of evolution. Artificial selection.

Discussion: Care should be exercised to deal with the theory of evolution as a theory. It is unwise and entirely unnecessary to insult those who on account of religious beliefs or for other reasons do not accept evolution. On the other hand, evolution is discussed so frequently and there is so much uninformed opinion about it that some information should be given in the biology course. The teacher will do well to keep her own ideas regarding evolution to herself and attempt to force neither acceptance nor rejection of the theory.

The topic may well be introduced by discussions of adaptations to environment observed in nature and mentioned from time to time in the course. It is well to limit discussion to plants and lower forms of animal life. The various factors of use and disuse of organs, heredity, sudden mutations, and survival of the fittest should be presented as forms of the theory.

In connection with natural selection some work on artificial selection such as selective planting and breeding, hybridizing, budding, and grafting should be introduced. Demonstrate budding and grafting in the laboratory; if the instructor is sufficiently skilled, actual budding and grafting should be done.

XV. Generalizations and Reviews.

Determination of where to begin and stop with generalization is a constant organization problem. Few generalizations have been introduced up to this point in the course. Under this plan some rather vital subject matter may have been omitted. It is hoped that time may be saved toward the end of the course for generalization on at least some of the following topics. Thus will be secured review

of specific topics together with presentation of material which did not fit in the regular outline.

1. Adaptations. The illustrations of adaptations in nature are legion. Among the many to be emphasized the following are of more than ordinary importance: (a) Adaptations of insects and flowers for pollination. (b) Adaptations of various plants for seed dispersal. (c) Mimicry and protective coloration in plants and animals. (d) Adaptations of plants to soil and to climatic conditions of moisture, temperature, and wind; leaf and root adaptations of hydrophytes and zerophytes. (e) Adaptation and evolution.
2. Cell structure in pollen, roots, seeds, stems, leaves, protozoa, bone, and muscle.
3. Osmosis in roots, stems, and animal digestion.
4. Nutrients in seeds, roots, stems, diet. This subject may also be included with digestion in animals and manufacture of food in plants.
5. Processes carried on by both plants and animals: (a) Digestion. (b) Respiration. (c) Circulation. (d) Excretion. (e) Reproduction. Review of hygiene.
6. Brief work on classification; somewhat greater detail in dealing with birds and flowers.

The Differentiated Course

About twelve weeks of the course is reserved for differentiation. The purpose with differentiation is to make provision for treatment of subjects of special interest or moment to the various classes studying biology. The following paragraphs, therefore, are to be viewed primarily as suggestive and illustrative of materials which may be included:

Differentiation may take the form of elaboration of topics dealt with in the uniform course. This type of development will probably be found most profitable with the following topics:

Elaborations of Topics of the Uniform Course

1. Fruits and Seeds (Topic V). Seed testing boxes may be prepared and scientific testing of seeds taught. Another field for study in certain sections is that of weed seeds and weeds—kinds, conditions of growth, dispersal of seed, economic losses due to weeds, weed elimination, and the like.
2. Stems. Fungi. (Topics VII and VIII). Everywhere in Montana but especially in timber regions throughout the western part of the state, Topic VII (stems) very appropriately leads to detailed study of trees, wood, and forests. Work on ferns, mosses, and lichens may be annexed to tree study. Recognition of various kinds of trees and wood, values of forests, and preservation from destruction by fire, excessive cutting, and disease are important sub-topics. If blights and fungi harmful to trees are the last subjects treated, a logical transition is made to an elaboration of Topic VIII (fungi) which may be introduced by a study of rusts, smuts, and mildews.
3. Bacteria. Protozoa. (Topics IX and X). More detailed study of bacterial diseases (especially tuberculosis, pneumonia, diphtheria, and

typhoid fever) and of common protozoan diseases (malaria, sleeping sickness, and smallpox) are well worth while. Defences of the body against the micro-organisms of disease and the theory of immunization may form the basis for pertinent discussions extending the work of the uniform course.

4. Fishes nd Frogs. Mammals. (Topic XI.) Study of marine forms and of mammals had probably better be introduced with this topic if introduced at all.
5. Hygiene. (Topic XII.) The evils of stimulants, narcotics, and drugs, and the uselessness or evil effects of most patent medicines may form the basis for consideration in an extension of this subject. Coffee, tea, tobacco, and alcohol have generally been accorded considerable time in earlier courses, but further treatment may well be given them. The increased consumption of drugs is arresting the attention of our social workers. Warnings are issued especially against morphine, heroin, and cocaine. In this connection drug addiction resulting from headache tablets and other patent medicines should be treated. Secure material from Narcotic Education Association, Pasadena, Cal., and from International Narcotic Society, Henry Building, Seattle, Wash.
6. Variation, Mutation, and Adaptation. (Topic XIV.) Desirable additional work on these subjects coupled with heredity may be given. The work of Mendel, Burbank, members of the U. S. Department of Agriculture, and of other biologists dealing with artificial selection may be studied; some results of selective planting, budding, slipping, and grafting can be demonstrated especially if the instructor remains in the same school for a number of years; illustrations of selective breeding of domestic animals can be found in many communities; treatment of eugenics may be given if the instructor has the type of personality which will make this study effective.

The elaborations suggested above are in each case related to one or at most two topics of the uniform course and have for their purpose more detailed development of these topics. Those which follow comprise materials which really form separate major objectives of the course. Some of these materials may best be presented when a number of weeks is reserved for their exclusive consideration; others may be more effectively developed if spread over a longer period of time and allowed to permeate the course, being treated intermittently in connection with a variety of topics.

Extensions Involving Additional Major Aims

1. Appreciation of nature. This objective undoubtedly enters into consideration with every biology course. However, the amount of emphasis placed upon it varies greatly. If any marked results are to be obtained, this motive must be kept in mind throughout the course; it is not taught or learned in a few days.

   Among biology subjects especially useful in developing appreciation of nature are flowers, trees, fish, birds, and wild life. Recognition of a considerable number of species and direct observation of characteristics and habits of individuals add greatly to interest and appreciation. One practical outcome of study of flowers and trees

(shrubs and vines included) may be some landscape gardening about the school yard by the class. If the school is located near good trout streams, reports on habits of fish and on fishing laws may be given by enthusiastic fishermen among the pupils; care must be taken that this part of the course does not degenerate into a mere swapping of fish stories. The songs, plumage, and habits of birds form absorbing studies. Every locality has interesting species of wild life. Practically every section of the state will justify study of one or more types of game and necessary protective measures. Many pupils enjoy keeping ''hobby books'' on some one subject selected from a list; such as, flowers, house plants, birds, dogs, trees, horses, etc.

2. Economic values. This objective may be stressed with every topic treated in the biology course. Effort has been made to keep economic discussions in the background in the uniform course; some further treatment may be desirable. Care needs be exercised in this matter; in some biology courses economic values lie like an incubus over every activity.

3. Agriculture. In an agricultural region this subject forms a practical extension to the uniform course. It may be treated in a separate block of time or in conjunction with the various topics of the course. In biology the study of agriculture probably connects most appropriately with plants, roots, stems, leaves, seeds, and fruits. In addition, poultry and livestock studies may be included with work on birds and mammals. In some courses special study is given to some particular local crop or to certain phases of agriculture, such as crop rotation, irrigation, summer fallowing, dry land farming, and other farming methods of especial concern to the community.

4. Great biologists. The study of famous biologists may be taken up at the time when the important discoveries of each are being discussed by the class; or a certain number of successive periods may be assigned to the subject; or periodic reports may be required of individual members of the class. The following lists of names are recommended:*

List A	*List B*	
Agassiz	Audubon	Mendel
Darwin	Burbank	Metchnikoff
Harvey	De Vries	Priestley
Huxley	Howard	Spencer
Jenner	Leeuwenhoek	Wallace
Koch	Linnaeus	Weissman
Pasteur	Lister	

5. Sex education. Some instructors regard the giving to pupils of a normal, healthy idea of sex one of the principal objectives of the biology course. The importance of this objective and the appropriate

* These lists of names of famous biologists have been secured through examination of the available biology textbooks. More elaborate treatment than mere mention of a scientist's name in connection with some law or process has formed the criterion for inclusion in the lists. The name of no person has been included in List A unless more than passing mention has been accorded in at least four of the texts examined; names in List B have been included by two or more textbook authors.

character of the biology course for teaching facts of sex will probably go unchallenged among teachers. Every parent will applaud good results achieved in this field. The only limiting factor is the personality of the teacher; better no sex facts than a knowledge which, on account of the way in which it is presented, the pupil will use irreverently, flippantly, or even immorally.

The uniform course presented in these pages includes some work on reproduction and associated subjects in connection with the study of seeds, cells, and flowers; further facts of reproduction and sex may readily be related to work with bacteria, protozoa, insects, fishes and frogs, birds, and heredity.

If more detailed treatment of reproduction is contemplated, it had probably better be given as a separate topic. Work may include asexual reproduction by fission, budding, grafting, growing from cuttings and spores. Illustrative material for laboratory study may concern cell life, bacteria, protozoa, ferns, yeast, and trees. Sexual reproduction may be followed from (1) conjugation in spirogyra through (2) fertilization in flowers and eggs of birds to (3) development of young in mammals.

No further study of reproduction or sex is recommended for mixed classes. If the sexes have been segregated throughout the course, additional work may be given. The method of segregating classes for certain lessons is too pointed and is not advised. In these cases physical training classes had better be used for any further sex information which may be attempted. More advanced sex education needs to be carried on only by those who are able to present the materials in a dignified and effective way. Occasionally the biology instructor is the one to do this; sometimes physical education teachers, men and women, explain sex matters to boys and girls respectively; frequently people in the community (ministers, doctors, nurses) are called upon to appear before classes. Unless they are known to possess ability to make a valuable presentation persons should not be asked to do this work; no one should be urged if he is reluctant to appear.

Topics treated may be varied but the following are recommended for inclusion: emotional and bodily changes at adolescence, menstruation (girls' classes,) seminal emissions (in boys' classes), the fallacy of sex necessity, principal venereal diseases. Excellent opportunity is offered in these lectures to build up ideals regarding sex. High school boys and girls will respond to discussions of chivalry, responsibility, control, the future of the race, choice of mates, and the like if properly presented.

The State Board of Health has a considerable number of social hygiene pamphlets for free distribution to teachers. *Keeping Fit* and *Youth and Life* exhibits also are available. The most valuable reference for the teacher is *High Schools and Sex Education* (1922); this book may be secured from the U. S. Public Health Service.

Laboratory Apparatus

The laboratories of other sciences, especially of general science, may be called upon to furnish the following materials for biology study: Bunsen burners or alcohol lamps, thermometers, beakers, glass tubing, rubber stoppers, test tubes, test tube holders and racks, ring stands, clamps, thistle tubes, bell jar, graduates, funnels, and chemicals needed for testing foods. If these pieces of apparatus are not available from other science laboratories, they should be purchased for the biology laboratory. Apparatus List A of the General Science Course will indicate kind, size, and amount of each.

Additional Apparatus Needed

The following list indicates first purchases to be made for the uniform course. It will be understood that supplemental apparatus for the differtiated course is to be secured.

Note: The number in the parentheses immediately following the description indicates the maximum number of pupils who may be served by the given amount of apparatus.

Quantity Recommended	Description	Approximate Price
1	**Dissecting Microscope,** Barnes type (2)	$ 3.50
72	**Microscopic Slides,** blank, glass, 25x75 mm	1.15
½ oz.	**Cover Glasses,** round, No. 2, dia. 18 mm	.90
1	**Forceps,** fine straight sharp points, lengths 4⅜" (2)	.17
1	**Section Razor,** both sides flat, for making microscopic sections	2.00
1	**Dissecting Set,** including scalpel, forceps, scissors, two dissecting needles, and 6" ruler, in leatherette case	1.75
1	**Breeding Cage,** all metal, folding, 12"x12"x16"	4.75
1	**Aquarium,** globe shape, capacity 3 gal	2.50
1	**Insect Killing Bottle,** cyanide prepared, capacity 8 oz	.40
12	**Dishes,** petri, double culture dish, 80 mm dia	6.00
1 set	**Microscopic Slides,** for Biology, set of 25 net	8.50
1	**Insect Spreading Board,** adjustable for all size insects, length 13" (4)	1.00
1	**Microscope,** compound, 2 eyepieces, 2 objectives, double circular nosepiece, magnifications of 50, 100, 215, and 430 diameters	74.50
	Small Germinators, Plant Boxes, Flower Pots } May be constructed by pupils	
	Total for Additional Apparatus	$107.12

Chemicals

*1x1 lb.	**Acid Acetic** C. P. 99.5% (Glacial)	$ .65
*1x1 lb.	**Acid Hydrochloric** Technical Concentrated	.40
*1x1 lb.	**Acid Nitric** Technical Concentrated	.65
1x4 oz.	**Agar Agar** Shreds	.80
1x1 oz.	**Albumen** Egg Scales	.35
*1x1 qt.	**Alcohol Ethyl** Denatured 95%	.55
1x1 lb.	**Aluminum Potassium** Sulphate Technical Crystals	.25
*1x1 lb.	**Ammonium Hydroxide** Technical Concentrated	.45
1x2 oz.	**Beef Extract**	.65
1x1 lb.	**Calcium Carbonate** Marble Chips	.20
1x4 oz.	**Calcium Phosphate** Dibasic Precipitated	.25
**1x1 lb.	**Carbon Bisulphide** Pure	.35
1x4 oz.	**Chloroform** U. S. P.	.30
1x4 oz.	**Chromium Potassium** Sulphate Pure Lumps	.20

1x1 lb.	Copper (ic) Sulphate Technical Crystals	.25
1x1 lb.	Cotton Absorbent	.85
1x1 lb.	Dextrose Pure Granular	.30
1x1 oz.	Diatase of Malt U. S. P.	.35
*1x4 oz.	Ether Sulphuric U. S. P. X.	.25
1x4 oz.	Fehling's Solution A	.25
1x4 oz.	Fehling's Solution B	.30
*1x1 lb.	Formaldehyde U. S. P. 40% Solution	.45
*1x1 oz.	Iodine, U. S. P. Resublimed	.75
1x4 oz.	Iron (ic) Choride U. S. P.	.25
1x1 lb.	Manganese Dioxide Native Powder	.25
1x1 oz.	Pancreatin U. S. P.	.45
1x1 lb.	Paraffin Solid	.18
1x1 oz.	Pepsin U. S. P. Powder	.45
1x1 oz.	Phenolphthalein U. S. P.	.35
**1x1 oz.	Phosphorus Yellow Sticks	.40
*1x4 oz.	Potassium Chlorate U. S. P. Crystals	.20
1x1 oz.	Potassium Iodide C. P.	.65
1x1 lb.	Sodium Chloride Fine White	.20
*1x4 oz.	Sodium Hydroxide C. P. sticks	.30
1x1 lb.	Sodium Hyposulphite Pea Size Crystals	.20
*1x1 lb.	Sodium Nitrate Pure Crystals	.25
1x1 pt.	Sodium Silicate Solution 40° Be. Technical	.25
1x4 oz.	Starch Arrowroot	.25
1x1 lb.	Sulphur Flowers Sublimed	.25
1 vial	Test Paper Litmus Blue	.10
1 vial	Test Paper Litmus Red	.10
1x1 lb.	Zinc Metal Technical Mossy	.40
	Total for Chemicals	$ 15.28

* Chemicals marked (*) cannot be sent by parcel post.
**Chemicals marked (**) can only be shipped by freight.

Additional Recommended Apparatus

Additional apparatus should be purchased from year to year to make the biology laboratory equipment more complete. A greater number of microscopic slides than indicated above is desirable. As financial conditions warrant, it is recommended that some provision for visual instruction be made through supplying lantern slides and means of projection. In some schools the beginnings of a natural science museum have been made. Charts are very valuable in biology teaching; models are more useful but also more expensive than charts.

Quantity Recommended	Description	Approximate Price
1	Binocular, bird or nature study glass, wide field, with shoulder strap and case	$ 8.00
1	Balance, Harvard Trip, agate bearings, beam weighs 10 g to 0.1 g, sensibility 5 cg	12.00
1 set	Weights, brass, in wood block, 1 g to 1000 g, including 1 g, (2)2g, 5 g, 10 g, (2)20g, 50 g, 100 g, (2)200 g, 500 g, and 1000 g	8.75
1	Funnel, glass, 90 mm dia.	.36
1	Graduate, cylindrical, graduated up and down, 100 cc by 1 cc	.80
1	Graduate, cylindrical, graduated up and down, 250 cc by 2 cc	1.25
1	Graduate, cylindrical, graduated up and down, 500 cc by 5 cc	1.60
1	Lamp, alcohol, round, glass, 4 oz. (If gas is available specify: 1 Bunsen Burner, new form, with needle valve gas control, $.65; 3 ft. Rubber Tubing, white, ¼" dia., 1/16" wall, $.42)	.55

12	**Pipettes,** with rubber bulbs (medicine droppers)	.30
1	**Thermometer,** engraved double scale, -10° to 110° C and 10° to 220° F, length 12″	2.00
1	**Demonstration Eyepiece with pointer.** Instructor and pupil can view object at the same time	45.00
1	**Plant Press,** with six sheets absorption paper, 12″x16″	3.50
1 pkg.	**Insect Pins,** for mounting insects, 100 per pkg., size No. 3	.25
1	**Aquarium,** aluminum frame, slate bottom, 12 gal., 20½″x 13″x13″	17.50
1	**Specimen Mount,** 5″x6″	.28
1	**Specimen Mount,** 8″x12″	.50
1	**Sterilizer, Arnold's,** steam, 11½″ high, 10½″ dia	14.00
1 set	**Microscopic Slides,** for Biology, special set of 25 net	8.50
1	**Anatomical Model of the Human Heart** net	15.25
1	**Anatomical Model of the Human Eye** net	10.00
1	**Anatomical Model of Human Ear** net	12.75
1	**Anatomical Model of the Human Lungs** net	5.25
1	**Anatomical Model of the Human Trunk** net	34.00
1 set	**W. & A. K. Johnston's Physiology and Anatomy Charts,** on solid chart head and tripod stand, with manual, 8 in set net	8.50
	Total for Additional Recommended Apparatus	$210.89

PART IV. CHEMISTRY

General science and biology have been treated with great detail and definiteness for two principal reasons. In the first place these sciences are sometimes taught by instructors whose major preparation has been in some department other than science; it is felt, therefore, that detailed suggestions regarding the teaching of these sciences might be found of considerable value. In the second place general science and biology are not standardized to any appreciable extent; in order that some uniformity, as well as variety, of content in courses may be discoverable rather long treatment was accorded these sciences.

When we enter the fields of chemistry and physics an entirely different situation is encountered. Teaching of these courses is seldom undertaken by an instructor unless he has had considerable training in them. Furthermore, despite the new developments which are continually taking place, much of the material to be taught in these sciences remains fairly well standardized due to their long tenure of position in the high school program and the rather general disposition of educators to regard them as pure sciences. For these reasons extended treatment of them is not so necessary as with general science and biology.

General Principles

Aims

The aims of chemistry instruction are summed up by the N. E. A. Committee on Reorganization of Science in Secondary Schools whose report has been referred to in earlier parts of this course. The chemistry teacher does not have much difficulty in justifying his course since the ascending vocational, civic, and health aims with chemistry are rarely if ever questioned. The discussion of content of the course will bring out in detail the way in which vocational, civic, and health aims may be realized.

Theory

Some study of theory is essential in a high school chemistry course. Observation would lead to the comment that pupils are usually better versed in practical applications and descriptive material than in theory. It seems that there are so many interesting matters to be treated in the chemistry course that the more difficult and less inviting theory is in danger of becoming submerged.* Applications and description should be included; the fundamental principles upon which the industrial processes rest must also be taught if chemistry in our high schools is to reach its highest usefulness. The theory is difficult; therefore judgment must be used to treat only those phases of it which are pertinent to an elementary course and comprehensible to pupils with a high school background. Moreover, care needs to be exercised in allowing sufficient time for thorough work with the theory taught; this time may be gained by condensing discussion of descriptive chemistry.

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* See, for instance, articles by Cornog and Colbert in the Journal of Chemical Education and School Science and Mathematics for 1924. These writers recommend the following apportionment of time in high school chemistry: Descriptive, ½; useful applications, ¼; theory, ⅛; problems and equations, ⅛.

Problems and Experimentation

Theory is made understandable principally through problems and laboratory exercises. Only through these means do pupils secure drill in the application of theories learned and understanding of chemical processes described.

Industrial Chemistry

It must not be concluded from what has been said concerning theory and problems that industrial applications of chemistry should be ignored. Chemistry plays such an important role in modern life that a high school course which neglects to give glimpses of industrial chemistry fails in one of the important fields which it should cover. That the view given of industrial chemistry will at best be a very fragmentary one is entirely evident if one considers that new discoveries in chemistry are very numerous—an average of sixty each day according to one dependable authority. It is futile to attempt to have the high school course in chemistry treat industrial applications with even approximation to completeness. Some vision of the extensiveness of the field may be and should be given by indicating the principal developments in certain important industries.

A Balanced Course

At one extreme of chemistry instruction is the theorist who makes his subject repulsive to high school pupils by insistence upon too many abstractions; at the other extreme is the teacher who emphasizes practical matters to such an extent as to give pupils little or no background for understanding the applications taught. The judicious chemistry teacher will steer a middle course by balancing emphasis placed upon theory and practical phases of the subject. The high school chemistry course is made interesting and useful to pupils by attention to both theory and industrial applications and by allowing neither of these to be crowded out by the other.

Plan of the Chemistry Course

A Year Course

The field of chemistry is so vast that it is extremely difficult to limit course of study material.* Because of the importance and extensiveness of chemical knowledge the thought is sometimes expressed that more than one year should be given to the subject. In larger high schools such a plan may be feasible, but in smaller schools it is impracticable thus to extend the chemistry course. Consequently the course here outlined is intended for one year of chemistry study.

Required and Optional Topics

As one becomes acquainted with the syllabus which follows it will become apparent that the material given under required topics is very much restricted. Attempt has been made here to include the most essential topics in the most important fields. It is not intended that the time of the whole year should be given over to these required topics, but that much work with optional topics will be introduced.** It will be noted further that many of the optional topics are nothing more than elaborations of required topics; in these cases a more detailed study of the required topic is made optional. The time assignments in each case refer to required topics only.

* A very excellent course of study in chemistry is that of the Committee of Chemical Education of the American Chemical Society. This course appeared in the Journal of Chemical Education, May, 1927.

**Attention is directed also to the discussion of differentiation on pages 67-68.

Material of the Uniform Course

It will be observed that practically every topic listed in this syllabus allows of laboratory experimentation. The intention of this course so far as laboratory work is concerned may be stated as follows: Have experiments performed on all starred topics and on as many others as time and laboratory equipment will permit.

I. Introduction. (Two days)

Required: What chemistry is. Physical and chemical changes.* Combustion.* Law of conservation of matter.

Optional: Alchemy. The history of chemistry. The phlogiston theory and other historic views regarding combustion.

II. Elements, Compounds, Mixtures. (Three days)

Required: Distinction between elements and compounds.* Distinction between compounds and mixtures.* Law of definite proportions.

III. Oxygen. (Three days)

Required: Occurrence and discovery (brief treatment). Laboratory preparation.* Physical and chemical properties.* Oxidation. Commercial uses. Ozone.

Optional: The connection of Scheele, Priestley, and Lavoisier with the discovery of oxygen. Alternative ways of laboratory preparation. Spontaneous combustion. Kindling temperature. Principles employed in various ways of quenching fire. Commercial preparation by liquefaction of air or electrolysis of water. Oxidation of body fuels in animals. Decay of organic matter through oxidation aided by bacteria of decay. Burning of illuminating gas in Bunsen burner, gas stove, and gas light. The principle of the stove and kerosene lamp. The Davy safety lamp. Oxy-hydrogen blowpipe. "Lime-light." Modern blast lamp. Pulmotor. Oxygen helmet. Deep-sea diving. Water purification, deodorization, and bleaching by ozone.

IV. Hydrogen. (Three days)

Required: Occurrence. Laboratory preparation.* Properties.* (Do not allow pupils to light a hydrogen jet or to ignite explosive mixtures of oxygen and hydrogen. Reduction. Uses.

Optional: Alternative ways of preparing hydrogen. The Kipp Generator. Commercial preparation. Liquefaction of hydrogen. Formation of compounds with oxygen, chlorine, sulphur, nitrogen, and carbon. Reduction and oxidation as opposite and corresponding actions. Hydrogen, coal-gas, and helium as fillers for balloons and dirigibles. Hydrogenation of oils.

V. Hydrogen and Oxygen Compounds. Solutions. (Three days)

Required: Water: Solvent power. Solution and crystallization.* Purification (Brief). Composition by volume shown by electrolysis.* Composition by weight.

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* Items marked thus are suitable for laboratory work.

Hydrogen peroxide: Composition. Preparation.* Chemical properties. Uses.

Optional: Solution and suspension. Colloidal solution. Dilute and concentrated solution. Saturated and super-saturated solution. Evaporation—water vapor—condensation—rain cycle. Water in the soil. Water of crystallization. Crystal forms. Efflorescence, deliquescence, precipitate, effervescence. Heat of solidification, fusion, vaporization, condensation. Various methods for purifying water. Electrolysis of water and synthesis of oxygen and hydrogen to form both steam and water. Commercial hydrogen peroxide. Hydrogen peroxide as antiseptic and bleaching agent. Law of multiple proportions.

VI. Gases and Their Measurement. (Six days)

Required: Standard conditions of temperature and pressure. Varied pressure and Boyle's Law.* Varied temperature and Charles' Law (including absolute temperature scale. The combined laws and equation $\frac{VP}{T} = \frac{V'P'}{T'}$ [1]. Molecular theory as applied to gases. Avogadoro's principle. Gay-Lussac's Law of Volumes. Kinetic theory of gases.

Optional: Robert Boyle, Jacques Charles. Joseph Gay-Lussac. Amadeo Avogadoro. Derivation of the formula for the gas equation. Correction for aqueous tension.

VII. Carbon and Oxygen Compounds. (Four days)

Required: Carbon dioxide: Occurrence in nature. Carbon-oxygen cycle. Laboratory preparation.* Properties.* Lime water test.* Commercial preparation, storage and uses.

Carbon monoxide: Composition, Occurrence. Physiological effects and dangers.

Combining weights of carbon and oxygen in these gases.

Optional: Detailed study of carbon-oxygen cycle between plants and animals. Carbonates. Liquid carbon dioxide and its solidification. Various ways of commercial preparation. Soda water, history and modern method of preparation. Carbon dioxide as fire extinguishing agent. Choke damp of the coal mine. Natural outflows of carbon dioxide. Carbonic acid. Preparation of carbon monoxide. (Exercise great care and perform only as demonstration experiment.) Occurrence of carbon monoxide in automobile exhaust, in coal fires, in illuminating gas. White damp of the coal mine. Physiological effects of carbon monoxide. Reduction of metallic oxides by carbon monoxide. Commercial gas of Eastern and Western United States. Producer gas. Water gas. Coal gas.

VIII. Hydrogen Chloride and Chlorine. (Four days)

Required: Hydrogen Chloride: Properties of hydrochloric acid.* Chlorides.*

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1 Give many problems in connection with Boyle's Law, Charles Law, and the gas equation.

* Items marked thus are suitable for laboratory work.

Chlorine: Occurrence in nature. Poisonous qualities. Preparation and properties of Chlorine.* Commercial production and uses.

Optional: Preparation and properties of hydrogen chloride. Volumetric composition of hydrogen chloride. Formation of chlorides. Silver nitrate test for chlorides. History of discovery of chlorine. Electrolysis of salt water and its products. Liquid chlorine. Chlorine water and bleaching powder. Preparation of bleaching powder. Chlorine as bleaching agent. Chlorine as disinfectant, chlorine treatment for colds. Chlorinating water for drinking purposes. Use of chlorine as poison gas. Affinity of chlorine for hydrogen. Hypochlorous acid. Dakin's solution.

IX. **Atoms and Molecules.** (Three days)

Required: The atomic theory. Atomic weights. Molecular weights. (This is a desirable place to introduce reviews of physical and chemical change, the law of definite proportions, the law of conservation of matter, Charles' law, Boyle's law, Avogadoro's hypothesis, and Gay-Lussac's law of gas volumes.)

Optional: John Dalton. Reasons for acceptance of the atomic theory. How the molecular weight of oxygen is determined. How the molecular weight of any other gas is determined. Gram-molecular weight and volume.[1]

X. **Equations and Calculations.** (Eight days)

Required: Symbols. Formulas. Equations. Calculations.[2]

Optional: Problems on computing molecular weight from formula, percentage composition from formula, formula from percentage composition. More elaborate problem work on calculations for weight and volume.

XI. **Acids, Bases, and Salts.** (Five days)

Required: Acquaintance with chemical and common names and formulas for sulphuric, hydrochloric, and nitric acids, and for sodium, potassium, calcium, and ammonium hydroxides. Tests for acids and bases.* Characteristic composition of acids and bases. Reactions of acids with bases and with metals.* Tests for salts.

Optional: Commercial values of principal acids and bases. Commercial values of salts. Normal, acid, and basic salts.

XII. **Ionization.** (Three days)

Required: Electrolytes and nonelectrolytes.* Theory of ionization.

Optional: Svante Arrhenius. Low freezing and high boiling points of electrolytes. Explanation of neutralization of acids by bases. Hydrolysis. Experiments and equations for electrolysis of salt solution, of hydrochloric acid, and of water. Displacement or electromotive series. Electroplating and electrotyping.

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1 Give problems on molecular weights and molecular weights and volumes.
2 Assign many exercises involving formulas, equations and calculations.
* Items marked thus are suitable for laboratory work.

XIII. **Valence and Nomenclature.**[1] (Two days)

Required: How valence is determined. Radicals. Variable valence. Names of compounds and their meanings.

Optional: Exceptions to valence. Equivalent weights.

XIV. **Sulphur and Its Compounds.** (Five days)

Required: Sulphur as element: Occurrence. Allotropic forms. Uses. Sulphur compounds: Hydrogen sulphide, preparation and properties.* Sulphuric acid, commercial preparation and values. Its properties.* Sulphates. Uses. Carbon disulphide.

Optional: Deposits of sulphur in Japan, Spain, Mexico, Sicily, and Louisiana. Purification of natural sulphur. The hot water-compressed air method of mining sulphur. Vulcanizing of rubber and the rubber industry. Matches. Insecticides containing sulphur. Manufacturing processes in which sulphur is used. Methods for commercial preparation of the various forms of sulphur. Sulphur springs. Hydrogen sulphide as a test for metals. Tarnishing of silver and cleaning of metal surfaces. Sulphides derived from hydrogen sulphide. Sulphur dioxide. Bleaching and antiseptic qualities of sulphurous acid. Sulphites and bisulphites. Calcium bisulphite and paper making. Contact process of manufacturing sulphuric acid. Lead-chamber process of manufacture of sulphuric acid. Concentrated and dilute sulphuric acid interaction with metals. Reaction of sulphuric acid with bases and metallic oxides. Uses of sulphuric acid in manufacture of explosives, dyestuffs, hydrochloric and nitric acids, fertilizers, sodium bicarbonate, alum, glucose, refining of petroleum, storage batteries. Important sulphates, especially barite, gypsum and plaster of Paris, zinc sulphate and white vitriol, copper sulphate and blue vitriol, iron sulphate and green vitriol or copperas, sodium sulphate and Glauber's salts, magnesium sulphate and Epsom salts. The barium salt test for the SO_4 ion. Manufacture of carbon disulphide. Carbon disulphide as a solvent.

XV. **The Atmosphere. Nitrogen and Its Compounds.** (Six days)

Required: Nitrogen: Occurrence in atmosphere. Inertness.
Ammonia: Laboratory preparation.* Liquefaction. Solubility.* Ammonium hydroxide. Ammonium salts. Commercial preparation and distribution. Importance and uses.
Nitric acid: Properties.* Uses. Nitrates.

Optional: Air as a mixture. Liquefaction of air. The Dewar flask. Removal of oxygen and nitrogen from liquid air. The rare gases of the atmosphere and their discovery. Discovery of nitrogen. Fixation of nitrogen by Oswald and Birkeland-Eyde processes. Fixation by plants. The nitrogen cycle in nature. Muscle Shoals. Liquefied ammonia gas and ammonia water. Ammonia and the ammonium radical. Recovery of ammonia as by-product of destructive distillation of coal. The Haber and cyanamide processes for

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1 Give numerous problems on valence and considerable drill on nomenclature and valence.

* Items marked thus are suitable for laboratory work.

manufacturing ammonia. Distribution of ammonia in liquefied form, as ammonium hydroxide, and as ammonium salts. The Solvay process for making sodium carbonate. Electric refrigeration. Manufacture of artificial ice. Ammonia water as a cleaner. Ammonium chloride and the manufacture of dry cells. Ammonium nitrate and explosives. Ammonium sulphate as fertilizer. Ammonium carbonate and manufacture of baking powder. Nitrous oxide as anaesthetic. Nitric oxide. Nitrogen peroxide. Manufacture of nitric acid from sodium nitrate and sulphuric acid. Oxidizing properties of nitric acid. Reaction of nitric acid with bases, metals, and metallic oxides. Calcium nitrate as fertilizer. Natural deposits of nitrates. Nitrates and the soil. Silver nitrate in photography and medicine. Test for the NO_3 ion. Aqua regia. The NO_3 group in explosives. The story of collodion and celluloid. Artificial silk.

XVI. Sodium and Potassium Compounds. (Five days)

Required: Metals and non-metals. Properties of sodium and potassium as elements.* Common salt and its value to the chemist. Sodium carbonate and sodium bicarbonate.* Sodium hydroxide, its properties and uses.* Sodium nitrate and its uses. Corresponding potassium compounds and their uses. Flame tests and spectrum analysis.

Optional: Method of preparing sodium and potassium. Salt mining. Rock salt. Recovery of salt from salt water. Preparing salt for table use. Salt and digestion. Salt and the manufacture of ice cream. Salt as preservative. Salt as the source of supply of chlorine and sodium. The Solvay process of manufacturing sodium carbonate. The Leblanc process. Soda ash. Washing sodas. Baking powder. Production of carbon dioxide from baking powder. Cream of tartar, alum, and phosphate baking powders. Chemical fire extinguishers. Foamite. Castner and Nelson methods for securing sodium hydroxide and chlorine by electrolysis of brine. Mercerizing of cotton goods. Soaps. Bleaching with sodium compounds. Mining, purification, and commercial values of Chili saltpeter. Sodium nitrate as fertilizer. Sodium nitrate and the glass industry. Sodium nitrate in the manufacture of nitric acid, sulphuric acid, potassium nitrate, and sodium nitrate. Sodium cyanide and gold extraction. Preparation, properties, and uses of sodium peroxide, sodium sulphite, sodium thiosulphate, sodium sulphate, sodium silicate. Shaving and soft soaps. Black gunpowder. Potassium nitrate as preservative for meats. Potassium compounds as fertilizers. Preparation of potassium carbonate from wood ashes. Asiatic potassium nitrate beds. Potassium beds of Stassfurt and Alsace. Potassium chlorate and its uses in fireworks, safety matches, and medicine. Color tests for sodium and potassium. Spectrum analysis. Bunsen, Kirchoff, and the spectroscope.

* Items marked thus are suitable for laboratory work.

XVII. Carbon and Its Compounds. (Eight days)

Required: Carbon as element: Allotropic forms and properties. Destructive distillation.*

Hydrocarbons: The methane series and principal products.* Ethylene, acetylene, and benzene series (briefly).

Carbohydrates: Cellulose.* Starch.* Sugars.*

Optional: Diamond mines. Famous diamonds. Artificially made and imitation diamonds. Uses of diamonds. Artificially made graphite. Uses of graphite. How lead pencils are made. The electric furnace. Principal coal deposits of the world. How coal is formed. Smoke. The automatic stoker. Carbon black, its manufacture and uses. Reducing ores with coke. Charcoal and the gas mask. Boneblack as filter and purifier. Destructive distillation of wood. The beehive oven. Modern methods of destructive distillation of coal. Manufacture of coal gas, producer gas, and water gas. Pintsch gas, Blau-gas, natural gas. Nature of hydrogen, candle, Bunsen, and acetylene flames. How candle flame is measured. How natural gas, petroleum, and water are stored in the earth. Famous oil regions. Refining of petroleum. Cracking of oils. Fuel oils. Lubricating oil. Oil burning engines and heaters. Coal tar and dyes. The dye industry. Alcohols. Uses of alcohol in industry. Aldehydes, especially formaldehyde. Formalin, paraformaldehyde, and formacone. Mormic, acetic, palmitic, stearic, and oleic acids. Esters. The perfume industry. Flavoring extracts. Soaps: laundry, toilet, transparent, floating naphtha, scouring, liquid, shaving, soap powders. How soap cleanses. Glycerin, nitroglycerin, and dynamite. Hydrogenation of oils. Oleomargarine and butter. Linseed oil, paints, and varnishes. How calcium carbide is made. How acetylene is made and distributed. Benzene and toluene. T.N.T. Structural formulas. Composition, occurrence, and uses of oxalic, tartaric, citric, malic, lactic, butyric, carbolic, and prussic acids. Nitrocellulose and smokeless powder. Collodion, manufacture and uses. Cotton, linen, wool, and silk. Mercerization of cotton. Testing of textiles. Removal of stains from clothing. The iodine test for starch. Dextrose and glucose. Manufacture of corn sirup. Barley sugar and caramel. The cane and beet sugar industries. Manufacture of sugar. Foods and diet. Identification of commercial articles such as carbona, energine, pyrene, bakelite, crisco, prestolite, newskin. Preparation, properties, and uses of methyl chloride, chloroform, carbon, tetrachloride, iodoform, cyanogen, ether, acetone, cream of tartar, anilene, naphthalene, anthrocene, asphalt, oil cake, turpentine, rosin, rubber. The field of organic chemistry.

XVIII. The Periodic System. (One day)

Required: Presentation and values of the periodic table.

Optional: Irregularities and inconsistencies in the table. The principle of atomic numbers. Dimitri Mendelejeff. H. G. J. Moseley.

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* Items marked thus are suitable for laboratory work.

XIX. **The Halogens.** (Two days)

Required: Members of the family. Occurrence, properties, and principal uses. Preparation and properties of iodine or bromine.*

Optional: Sources of commercial supply of halogens. Methods of laboratory preparation. Commercial preparation of bromine and iodine. Properties and uses of the halogen acids and salts. Moissan and the isolation of fluorine.

XX. **Phosphorus as a Member of the Nitrogen Family.** (Two days)

Required: White and red phosphorus. Phosphoric acid. Superphosphate of lime.

Optional: Similarity of phosphorus to other members of the nitrogen family. Commercial preparation of phosphorus from phosphate rock. Phosphate rock deposits. Phosphorus pentoxide. Method of preparing phosphoric acid. Industrial uses of phosphoric acid. Manufacture of matches. Manufacture of safety matches. The principle of the common and safety match. The smoke screen. Phosphor bronze. The cap of the toy pistol. Method of manufacture of superphosphate of lime. Liebig and agricultural chemistry. Occurrence, preparation, properties, and uses of arsenic. Brittannia metal. Babbitt metal. Type metal. Wood's, Newton's, and Rose's metals. Uses of bismuth.

XXI. **Aluminum and Boron.** (Four days)

Required: Aluminum: Occurrence in nature. Properties and uses of the element. Alumina and its uses. Aluminum sulphate and alums.* Aluminum silicates.
Boron: Borax. Boric acid.

Optional: The formation of soil. Commercial production of aluminum. History of discovery of process for making aluminum. The aluminum industry. Thermite. Aluminum alloys. Alundum. Abrasives. Artificial sapphires and rubies. How aluminum sulphate is produced. Uses of aluminum sulphate. Mordants. Alums, their development and uses. Aluminum hydroxide. The making of brick, tile, stoneware, earthenware, china, and porcelain. Method of securing borax from colemanite. Borax in California. The boric acid supply of Tuscany. Antiseptic and preservative qualities of boric acid. Granite ware, agate ware, porcelain-lined ware, bathtub enamel.

XXII. **Silicon.** (Four days)

Required: Similarity to carbon. Occurrence. Importance as element. Silica and its uses. Water glass.* Glass.

Optional: Allotropic forms of silicon. Abundance in nature as silica and silicates. Amethyst, opal, agate, emerald, aquamarine, topaz, garnet, onyx, rhinestone. Flint and its uses. Petrified wood. Commercial preparation of silicon. Ferro-silicon. Duriron or tantiron. Carborundum and its uses. Silica ware. Clear fused quartz. The variety of silicic acids and their derivation. The variety of

* Items marked thus are suitable for laboratory work.

silicates. How water glass makes substances fireproof, waterproof, and decay proof. How glass is made. Glass blowing. Hard or Bohemian glass. Flint glass. Manufacture of window glass, plate glass, glass bottles, and glass dishes. Jena, non-sol, crown, and pyrex glass. Engraving cut glass. Annealing of glass.

XXIII. Calcium, Strontium, and Barium. (Six days)

Required: Calcium: Calcium carbonate and calcium bicarbonate. Softening of hard water.* Calcium oxide, properties and uses.* Calcium hydroxide, preparation and importance. Plaster, mortar, cement, and concrete.*

Strontium and Barium: Uses in pyrotechnics.

Optional: Calcium as element. Iceland spar, marble, and limestone. Temporarily and permanently hard waters. Equations for softening hard water by boiling, adding slaked lime, adding sodium carbonate, adding ammonium hydroxide, adding borax, employing the permutite process. How limestone beds were formed. How limestone caves have been formed. Stalactites and stalagmites. Boiler scale. Limekilns. The rotary limekiln. Limelight. Whitewash. Liming of soils. How cement is made. Fireproof construction. Reinforced concrete. Bleaching powder. Preparation, uses and reaction of plaster of Paris. Calcium compounds as fertilizers. Calcium chloride. Calcium carbide. Calcium cyanamide. Calcium fluoride. Calcium sulphide. Calcium acid sulphite. Calcium silicates. Barium and the manufacture of hydrogen peroxide. Barite and its uses.

XXIV. Magnesium, Mercury, Zinc, Lead, Tin. (Three days)

Required: Magnesium: Occurrence and uses.

Mercury: Uses of the element. Chlorides of mercury.

Zinc: Properties and uses of the element. Compounds of zinc.*

Lead: Galena ore as the source of supply. Properties and consequent uses of lead, especially in paint and plumbing industries.

Tin: Uses.

Optional: How magnesium is obtained. Talcum powder. Meerschaum. Asbestos. Flashlight preparations. Magnesium alloys. Epsom salts. Milk of magnesia. Cinnabar. How mercury is obtained. Amalgam filling for teeth. Bichloride of mercury. Zincblende and zincite. Roasting ore. How granular zinc is made. Zinc etchings. Galvanizing of iron. Zinc oxide. Zinc sulphide. Zinc chloride. The lead storage battery. Blast furnace method of extracting lead from galena ore. Lead shot. Manufacture of white lead. Chrome yellow as pigment. Poisonous effects of lead compounds. Uses of litharge and red lead. The paint industry. Method of extracting tin from tinstone. Recovery of tin from tinplate. Gray tin. Tin foil. How pins are made. Stannous chloride. Stannous hydroxide. Alloys: brass, bronze, german silver, solder, gun metal, bell metal, Brittannia metal, Babbitt metal, type metal, pewter. Resistance of metals to action of air, water, and acids.

* Items marked thus are suitable for laboratory work.

XXV. **Gold, Silver, Copper.** (Three days)

Required: Gold: Extraction from ore and uses.

Silver: Uses in tableware, medicine, and photography.

Copper: Occurrence. Properties. Uses. Copper compounds and alloys.*

Optional: Placer mining. The stamp mill. Cyanide process of extracting gold. Gold deposits of Montana. Gold deposits of the world. Gold leaf. Desilverization of lead by Parke's process. Plating tableware. Composition of sterling silver. Tarnish and its removal. Silver nitrate uses in medicine. Silver halides and photography. Copper of the Lake Superior region. Copper of Arizona. Copper of Utah and Montana. Refining of copper. Uses as conductor of electricity. Brass. Bronze. Phosphor bronze. Cuprous and cupric compounds. Composition of Fehling's solution and its action on glucose. Composition and uses of Bordeaux mixture. Copper plating. Electrotyping.

XXVI. **Iron.** (Six days)

Required: Extraction of iron. Pig iron. Cast iron, its properties and uses. Wrought iron. Steel and its uses. Tempering.* Iron pigments. Inks and ink stains.*

Optional: Important iron ores. How iron deposits are formed. Iron deposits of Lake Superior region. Important iron deposits of the world. Importance and value of iron. The blast furnace. The reverberatory furnace. Removing various kinds of impurities from iron. Slag. Uses of wrought iron. Bessemer process for conversion. Red short. Cold short. The open-hearth process. Duplex method. Production in the electric furnace. The critical range of temperature for steel. Casting ingots. Hardened, tempered, and case hardened steel. Manganese steel. Chromium steel, Nickel steel. Vonadium steel. High-speed steel. Silicon steel. Crucible steel. Rust. Venetian red. Sienna. Burnt sienna. Umber. Yellow ocher. Prussian blue. Blue prints. Lodestone. Effect of magnets and electric current upon various forms of iron and steel. Russian iron. Fools' gold. Copperas. Composition of ink. Blue-black ink. Removing ink stains. Nickel as a member of the iron family. Monel metal.

The Differentiated Course

Time Allowed

The required topics outlined above will on the basis of time assignments given them occupy about 20 weeks. If allowance of two additional weeks is made for tests, reviews, holidays, and the like, there will still remain 14 weeks of the year for differentiation.

Differentiation Through Including Optional Topics

In holding required topics to a much limited minimum it has been necessary to omit many related topics which are frequently included in high school chemistry courses. Some of the most important of such material is given under optional topics in the foregoing syllabus. While no teacher can hope to include all of these optional topics in a year course, it is expected that teachers will wish to include some of them in the time allowed for differentiation.

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* Items marked thus are suitable for laboratory work.

Differentiation Through Emphasis on Special Phases of Chemistry

Another form which differentiation may take consists in giving more detailed attention to some special phase of chemistry. While it is recommended that teachers and pupils do their own choosing of material to be studied, the following topics are suggested as suitable for such special study:

Chemistry of foods (especially for girls).
Chemistry of the household.
Chemistry of the garden.
Chemistry of one or more important industries (mining, smelting, agriculture, dyeing, the making of sugar, paper, soap, paints and varnishes, glues, glass, plastics, explosives, dairy products, leather goods, rubber, steel, petroleum, etc.)
Discoveries of great chemists.
Important inventions related to chemistry.
Chemistry and medicine.
Patent medicines.
Anaesthetics.
Antiseptics.
Chemical equilibrium.
Displacement series.
The rare elements.
Stains and their removal.
Radium and radio-activity.
Bleaching.
Photography.
Mordants.
Abrasives.
Alloys.
High temperatures and chemistry.
Solutions and ionization.
Colloids.
Spectrum analysis.
Volumetric analysis of soda, vinegar, milk.
Acidity of fruit juices.
Examination of canned goods for preservatives.
Fuels: solid, liquid, and gaseous.
Liquefaction of gases.
Precious stones.
Structure of the atom.

Laboratory Apparatus and Chemicals

In chemistry as in other sciences the laboratory should be considered a growing institution. The cost of beginning chemistry with a small class is not high, but as classes increase in size from year to year and as finances allow, more apparatus and more chemicals should be supplied for students in order that they may work in pairs rather than in larger groups. Similarly, more apparatus for demonstration work should be added as the course becomes established.

Adding to Equipment

In order that breakage during the year may be taken care of it is advisable to add 25% to the quantities of glassware specified in the following lists.

Breakage and Replacement

The amount of chemicals here indicated will be sufficient for a year's work with the number of pupils specified. Since, however, materials in the chemistry laboratory more than in any other laboratory, are constantly being depleted, it is doubly important that checks not less often than once a year be made and that replacements of glassware and chemicals be ordered during the spring or summer.

The following lists will supply the laboratory for ordinary experimentation. Where special phases of chemistry are introduced or unusual experiments are attempted it will be necessary to supplement the

Laboratory Lists

list here given. It should be mentioned also that the chemistry manual frequently contains lists of equipment needed to perform the experiments of the manual and that the principal laboratory supply houses are glad to furnish lists of recommended laboratory equipment. Lists A and C are to be considered as minimum; it may be possible to procure some of these materials by local loan or purchase or by drawing upon other laboratories of the school.

List A—Individual Apparatus

One set for each group of two pupils

Quantity Recommended	Description	Approximate Price
2	**Aprons,** rubberized cloth, size 42″ long, 34½″ wide	$ 2.00
2	**Beakers,** Pyrex, with lip, capacity 100 cc.....net	.38
1	**Beaker,** Pyrex, with lip, capacity 250 cc.....net	.25
2	**Blow Pipes,** brass, plain, 8″	.40
4	**Bottles,** wide-mouth, size 4 oz.	.60
1	**Brush,** test tube, plain	.06
1	**Bunsen Burner,** simple form	.35
1	**Wing Top,** brass	.15
1	**Clamp,** Stoddard's test tube	.14
2	**Clamps,** Mohr's, brass, for burettes, 2¾″	.44
1	**Crucible,** Coors Porcelain, No. 0, capacity 15 cc.....net	.10
1	**Crucible Cover,** Coors Porcelain, No. 0, dia. 42 mm.....net	.04
1	**Dish, evaporating,** Coors porcelain, No. 00A, capacity 70 cc.....net	.12
1	**Dish,** granite ware, 4 pt.	.40
1 pkg.	**Filter Paper,** 100 sheets, 10 cm dia.	.14
1	**Flask,** Erlenmeyer, Pyrex, 250 cc capacity.....net	.22
1	**Funnel,** glass, 75 mm dia.	.34
1	**Funnel Tube,** thistle top, straight stem, 30 cm long	.15
1	**Gauze,** iron wire, 200 mesh, 5″x5″	.10
3	**Glass Plates,** square, 4″x4″	.18
1	**Graduate, cylindrical,** graduated up and down, 100 cc by 1 cc	.80
1	**Jar,** waste, stoneware, 5-gallon size	2.50
1	**Mortar,** porcelain, with pestle, No. 0, capacity 60 cc.....net	.27
4	**Rubber Stoppers,** 1-hole, to fit No. 5620 test tubes, 5″x⅝″	.20
1	**Rubber Stopper,** 2-hole, to fit No. 5106P Flask, 250 cc.	.10
3 ft.	**Rubber Tubing,** white, 3/16″ dia., 3/64″ wall	.36
1 pc.	**Tubing,** gas, flexible steel, ¼″ dia., 24″ long, for Bunsen Burners	.30
1	**Sand Baths,** iron, 4″ dia.	.12
1	**Support,** ring stand, with two rings	1.00
1	**Support,** test tube, 13-tube	.90

1 vial	**Test Paper**, litmus, blue	.10
1 vial	**Test Paper**, litmus, red	.10
12	**Test Tubes**, 5″x⅝″	.30
1	**Tongs**, crucible, 9″ long	.30
1	**Trough**, pneumatic, galvanized iron, 4″x7″x10″	.85
	Total for Individual Apparatus	$ 14.76

List B—General Apparatus

Note: The number in the parentheses immediately following the description of some of the following items indicates the maximum number of pupils who may be served by the given amount of apparatus.

Quantity Recommended	Description	Approximate Price
1	**File**, round, 5″ (6)	$ .18
1	**File**, triangular, 5″ (6)	.18
1	**Boyle's Law Apparatus**, improved all metal mounting, with fixed J tube and meter scale	5.00
2	**Bar Magnets**, rectangular, polished steel, 15x1.9x0.7 cm	.35
1	**Electrolysis Apparatus**, length over all 40 cm	5.00
1	**Spectroscope**, direct vision form	18.00
1	**Balance**, Harvard Trip, agate bearings, beam weighs 10 g to 0.1 g, sensibility 5 cg	12.00
1 set	**Weights**, metric, in block; 1 mg to 20 g	2.75
6	**Reagent Bottles**, 250 cc. narrow mouth, glass stoppered, with name blown in glass, one each of the following: No. 101 Sulphuric Acid, con.; No. 104 Nitric Acid, con.; No. 105 Hydrochloric Acid, con., No. 108 Ammonium Hydroxide; No. 111 Sodium Hydroxide; No. 116 Blank	2.25
2	**Burettes**, Mohr's, capacity 25 cc, graduated to 0.1 cc	.70
1	**Chart of the Atoms**, lithographed in six colors, showing 40 atomic properties, including atomic symbol, atomic weight, atomic number size 42″x64″	5.00
2	**Clamps**, burette	1.10
2	**Clamps, Universal**, adjustable, with swivel jaws	1.70
1	**Condenser, Liebig's**, glass, 400 mm long	1.20
1 set	**Cork Borers**, brass, set of 3	.50
2	**Deflagrating Spoons**, brass, ¾″ cup, 15″ handle	.13
1	**Dish**, lead, 75 mm dia	.20
1	**Eudiometer**, Bunsen's, capacity 50 cc, graduated in 0.1 cc. net	4.25
1	**Flask**, distilling, 500 cc capacity	1.00
1	**Funnel**, glass, 200 mm dia	1.15
1	**Gas Generator**, Kipp's, 500 cc capacity	8.50
1	**Glass Plate**, blue cobalt, 4″x4″	.25
12	**Glass Rods**, stirring, 6″x3/16″ (8)	.35
1 lb.	**Glass Tubing**, 5 mm outside dia. (12)	.70
1	**Graduate**, cylindrical, graduated up and down, 500 cc by 5 cc	1.60
1	**Babcock Milk Tester**, 8 bottle size, complete	25.00
1	**Pipette**, volumetric, capacity 1 cc	.22
1	**Pipette**, volumetric, capacity 5 cc	.22
1	**Pipette**, volumetric, capacity 10 cc	.28
1	**Pipette**, volumetric, capacity 20 cc	.40
1	**Pipette**, volumetric, capacity 50 cc	.55
1 ft.	**Platinum Wire**, No. 28	3.36
1	**Ring**, iron, 4″ dia	.24
1	**Ring**, iron, 5″ dia.	.27
1	**Ring**, iron, 6″ dia.	.30
12	**Test Tubes**, 8″x1″	.80
1	**Thermometer**, engraved scale, -10° to 110° C, length 12″ (6)	1.25
1 spool	**Copper Wire**, 4 oz. spool, No. 24	.30

1 spool	Steel Wire, 4 oz. spool, No. 24	.10
1 sq. ft.	Copper Sheet, plain, No. 24	1.00
1	Tripod Magnifier, double lens, wide field	.80
	Diagrams (flow sheets) of industrial processes	
	Exhibits of raw materials and finished products of a number of the more common industries	
	Total for General Apparatus	$109.13

List C—Necessary Chemicals

One set for a class of ten

Quantity Recommended	Description	Approximate Price
*1x4 oz.	Acid Acetic C. P. Glacial	$ .45
*1x6 lbs.	Acid Hydrochloric Technical Concentrated	1.05
*1x7 lbs.	Acid Nitric Technical Concentrated	2.00
1x4 oz.	Acid Oxalic Technical Crystals	.22
*1x9 lbs.	Acid Sulphuric Technical Concentrated	1.25
1x4 oz.	Acid Tartaric U. S. P. Crystals	.30
*1x1 gal.	Alcohol Ethyl Denatured 95%	1.35
1x1 lb.	Aluminum Potassium Sulphate Technical Crystals	.25
1x4 oz.	Aluminum Metal Turnings	.30
1x1 lb.	Aluminum Sulphate Technical Crystals	.25
1x1 lb.	Ammonium Chloride Pure White Granular	.30
*1x4 lbs.	Ammonium Hydroxide Technical Concentrated	1.20
*1x1 lb.	Ammonium Nitrate Pure Granular	.50
1x1 lb.	Ammonium Sulphate Technical	.25
*1x1 lb.	Ammonium Sulphide C. P. Solution Light	.80
1x1 lb.	Barium Chloride Technical Crystals	.25
*1x4 oz.	Barium Dioxide C. P. (Peroxide)	.45
1x5 lbs.	Calcium Carbonate Marble Chips	.40
1x1 lb.	Calcium Chloride Technical Anhydrous	.45
1x1 lb.	Calcium Oxide Technical Lumps (Quicklime)	.30
1x1 lb.	Calcium Sulphate Native Gypsum Lumps	.20
**1x1 lb.	Carbon Bisulphide Pure	.35
1x1 lb.	Carbon Tetrachloride Pure	.35
1x5 lbs.	Cement (Portland) Pure	.35
1x1 lb.	Charcoal Wood Lumps	.30
1x1 lb.	Charcoal Animal Powder	.35
*1x1 oz.	Cobalt Nitrate Pure	.30
1x1 oz.	Copper Oxide Technical Powder	.20
1x1 lb.	Copper Sulphate Technical Crystals	.25
1x1 lb.	Copper Metal Turnings	.45
1x1 lb.	Dextrose Pure Granular (Glucose)	.30
1x4 oz.	Fehling's Solution A	.25
1x4 oz.	Fehling's Solution B	.30
1x1 oz.	Gelatine Ground	.20
1x4 oz.	Glycerine U. S. P.	.30
1x4 oz.	Hydrogen Peroxide U. S. P.	.20
*1x1 oz.	Iodine U. S. P. Resublimed	.75
1x1 lb.	Iron Metal Filings Fine	.25
1x1 lb.	Iron Sulphate (Ferric) C. P.	.75
1x1 lb.	Iron Sulphate (Ferrous) Technical Crystals	.20
1x1 lb.	Iron Sulphide (Ferrous) Lumps	.25
*1x1 gal.	Kerosene	.75
1x1 lb.	Lead Metal Foil	.60
1x1 lb.	Lead Acetate U. S. P. Powder	.45
*1x4 oz.	Lead Nitrate Technical	.20
1x4 oz.	Magnesium Carbonate U. S. P. Powder	.25

* Chemicals marked (*) cannot be shipped by parcel post.
**Chemicals marked (**) can only be shipped by freight.

*1x10 ft.	Magnesium Metal Ribbon	.20
1x1 lb.	Magnesium Sulphate U. S. P. Crystals	.20
1x1 lb.	Manganese Dioxide Native Powder	.25
1x4 oz.	Mercury Metal Virgin Grade (Quicksilver)	.85
1x1 lb.	Paraffin Solid	.18
**1x1 oz.	Phosphorus Yellow Sticks	.40
1x4 oz.	Potassium Bromide U. S. P. Granular	.35
*1x1 lb.	Potassium Chlorate U. S. P. Crystals	.30
1x4 oz.	Potassium Chloride Pure	.20
1x4 oz.	Potassium Ferricyanide Pure Crystals	.30
1x4 oz.	Potassium Ferrocyanide Pure Crystals	.25
*1x4 oz.	Potassium Hydroxide U. S. P. Sticks	.35
1x1 oz.	Potassium Iodide U. S. P.	.60
*1x4 oz.	Potassium Permanganate U. S. P.	.25
1x4 oz.	Potassium Sulphate Pure White	.25
1 oz.	Sodium Arsenite, C. P.	.35
*1x1 oz.	Silver Nitrate C. P.	.90
1x1 lb.	Sodium Bicarbonate Powder	.25
1x1 lb.	Sodium Borate U. S. P. Crystals (Borax)	.25
1x1 lb.	Sodium Carbonate Technical Crystals	.25
1x1 lb.	Sodium Chloride Fine White (Salt)	.20
*1x1 lb.	Sodium Hydroxide Technical Granular	.25
*1x1 oz.	Sodium Metal	.50
*1x1 lb.	Sodium Nitrate Pure Crystals	.25
1x1 lb.	Sodium Phosphate Dibasic Technical Crystals	.30
1x1 qt.	Sodium Silicate Solution Technical	.35
1x1 lb.	Sodium Sulphate Technical Crystals	.30
1x1 lb.	Starch Corn	.20
1x1 lb.	Sucrose Pure (Sugar)	.25
1x1 lb.	Sulphur Roll	.20
1x1 oz.	Tin Metal Pure Mossy	.20
1x1 lb.	Zinc Metal Technical Mossy	.40
	Ores. textiles, iron, soaps, and baking powders of various kinds.	
	Total for Chemicals Needed	$ 31.40

List D—Additional Desirable Chemicals

Sufficient for a class of ten

Quantity Recommended	Description	Approximate Price
*1x4 oz.	Acid Arsenous Technical Powder	$ .20
1x4 oz.	Acid Boric U. S. P. Crystals	.20
1x1 lb.	Ammonium Carbonate U. S. P. Lumps	.50
1x1 oz.	Ammonium Molybdate C. P. Crystals	.40
1x4 oz.	Antimony Metal Powder	.30
*1x4 oz.	Antimony Chloride (Antimonic) C. P. Fuming	.65
*1x1 oz.	Antimony Chloride (Antimonous) C. P.	.50
1x1 oz.	Arsenic Metal Crystals	.20
1x1 lb.	Asbestos Short Fibre	.25
1x1 lb.	Barium Sulphate Technical Powder	.25
1x1 oz.	Bismuth Metal Lump 98%	.35
1x1 oz.	Cadmium Metal Sticks	.30
*1x1 lb.	Calcium Carbide Technical	.25
1x1 lb.	Calcium Fluoride Technical Powder	.25
1x4 oz.	Chloroform U. S. P.	.30
1x4 oz.	Chromium Chloride C. P. Crystals	.75
1x1 oz.	Cobalt Chloride Pure	.30

* Chemicals marked (*) cannot be shipped by parcel post.

**Chemicals marked (**) can only be shipped by freight.

1x4 oz.	Copper Chloride (Cupric) C. P.	.45
*1x4 oz.	Copper Nitrate (Cupric) Pure	.35
1x4 oz.	Copper Sulphide (Cupric) C. P.	.50
1x4 oz.	Iron Chloride (Ferric) U. S. P.	.25
*1x1 oz.	Mercury Oxide (Mercuric) U. S. P. Red	.50
*1x1 oz.	Mercury Nitrate (Mercurous) C. P.	.60
1x1 pt.	Oil Cottonseed	.45
1x1 oz.	Phenolphthalein U. S. P.	.35
1x4 oz.	Acid Phosphoric U. S. P.	.40
*1x4 oz.	Phosphorus Red Amorphous	.65
1x4 oz.	Potassium Bitartrate U. S. P. Powder	.25
1x4 oz.	Potassium Chromate Pure	.30
1x1 lb.	Potassium Nitrate Pure	.25
1x4 oz.	Sodium Acetate Technical Crystals	.20
1x1 lb.	Sodium Hyposulphite Pea Size Crystals	.20
1x1 oz.	Strontium Chloride Pure	.20
1x4 oz.	Zinc Acetate C. P.	.45
	Total for Additional Chemicals	$ 12.30

* Chemicals marked (*) cannot be shipped by parcel post.

PART V. PHYSICS

General Considerations

Physics is undoubtedly the most firmly entrenched and the best standardized of all the science courses commonly found in the high-school program.

A Standardized Course

After some introductory study of such topics as states of matter, definitions, and physical measurements, the course quite regularly progresses to mechanics; then follow in various sequences units on heat, sound, light, magnetism, and electricity.

The very fact of such standardization leads to fear that form, logical organization, and tradition rather than pedagogical principles may determine content and methods. That such fear is not unfounded may be judged from the statements of the N. E. A. Committee on Reorganization of Science in Secondary Schools that many of our physics courses have sacrificed the interest of pupils to logical arrangement of traditional and sometimes out-of-date material, that laboratory work too often has been submerged or has been unsatisfactorily correlated with recitation, and that physics courses have not functioned as they should in helping pupils to understand higher types of vocations in which physics is fundamental. The teacher of physics needs to recognize a danger of over-standardization and uniformity in the material of his subject.

The most important major objectives in high-school physics study are those of efficient home membership, preparation for vocational usefulness,

Objectives

and worthy employment of leisure time. In our day utilization of electrical and mechanical appliances and of internal combustion engines is so general that a knowledge of physics is highly advantageous in one's daily activities; the vocational value of physics, especially to all forms of engineering and to many of the trades, is more generally accepted than that of any other science with the possible exception of chemistry; the leisure time objective finds realization here no less than with the other sciences.*

On account of mathematical computations needed in every physics course, a year of algebra should be a prerequisite to registration for high-school

Relation to Other Courses

physics. It is desirable that pupils should have had two years of mathematics exclusive of arithmetic before taking up physics. Since some of the material included in physics courses parallels content taught in general science and chemistry, it is recommended that pupils who have already studied these sciences be in physics given enough of the material for a thorough review and that they be assigned individual projects of an advanced nature whenever material duplicating earlier courses is encountered.

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* For a detailed discussion of physics objectives see John H. Dyer's **An Analysis of Certain Outcomes in the Teaching of Physics in Public High Schools**. University of Pennsylvania, Phila. (1927).

It is recommended that no physics course drop below the following minimum time allotments in the various major fields of physics instruction: mechanics, 8 weeks; heat, 3 weeks; magnetism and electricity, 6 weeks; sound, 2 weeks; light, 3 weeks. It will be observed that these minimum time requirements total 22 weeks; allowing two weeks for reviews, examinations, and such other interruptions of regular classroom work as may occur, there will still remain 12 weeks of a 36-week school year for special instruction suited to the individual conditions of any given local situation.

Emphasis Within the Course

Field trips are essential and important parts of a physics course. Some localities offer more opportunities for such excursions than do others, but every community has activities and industries which may be utilized for practical study of physical processes and phenomena.* Among field trips which will be found possible in various sections of Montana are the following:

Field Trips

For study of mechanics:
- City water works.
- Weather bureau.
- Hayloading devices.
- Irrigating systems.
- Machine shop.
- Roundhouse.
- Creamery.
- Sugar factory.
- Garage.

For study of heat:
- Creamery, sugar factory, or roundhouse (steam engines).
- Heating plants of various kinds.
- Artificial ice plant.
- Ore smelter.
- Fire department.
- Garage.

For study of electricity:
- Telephone office.
- Telegraph office.
- Dental office.
- Electric light station.
- Transformer station.
- Electric railway power station.
- Electric shop.
- Radio shop.
- Garage.

For study of sound:
- Music shop.
- Radio shop.
- Fire department.
- Garage.

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* Special attention is invited to the discussions of values and abuses of field trips given in Part I (p. 12) and Part II (p. 31).

For study of light:
- Electric light station.
- Electric shop.
- Optical shop.
- Garage.

Plan of the Course

Required and Optional Topics

The plan of listing required and optional topics already followed in the chemistry course is also employed in the physics syllabus. Many of the optional topics are elaborations of those listed as required; frequently they are practical illustrations of principles studied; sometimes they are repeated where their nature is such as to call for explanation in connection with two or more principles. In all of these cases it will be understood that the instructor is to exercise his judgment regarding which optional topics to take up and the time when they are to be introduced. From statements in other science courses contained in this bulletin, it will be apparent that there is no intention of ignoring practical devices, applications, and inventions. On the contrary, no high-school course in science can be considered satisfactory unless many of them are included. Their number in physics, however, is so large that it is necessary to choose; they have been listed as optional in order that choice may be unhampered.

Order of Topics

The order of topics should be considered as suggestive only and should be changed whenever it appears desirable to do so. An interesting and worth while suggestion has been made that the early part of the course could be varied and improved if the traditional work on metric measurements were postponed and some of the phenomena of physics were presented in terms of units, nomenclature, and terminology familiar to the pupil. Specifically this suggestion contemplates opening the course with the work on Hooke's law, the three laws of motion, parallelogram of forces, and measurements of friction, work and power; all computations would be made in units of the English system. Following this approach, the metric system would be introduced and made clear through review of some of the experiments already performed.

The Uniform Course

Note: Topics starred are intended for laboratory work. Many of the other topics should be taught with the assistance of laboratory experimentation—the more so taught the better. It is not intended that a double period should be given to each experiment; many starred topics will occupy less than a forty minute period.

Following are the required and optional topics of the uniform course:

I. Introduction

Required: Measuring of length, area, capacity, and weight by the English and metric systems and comparing results.* Problems on translation from one system to the other.

Optional: The standard meter and standard kilogram.

* Items marked thus are suitable for laboratory work.

II. Absorption and Diffusion.

Required: Absorption of gases in liquids and in solids.* Diffusion of gases and liquids.* The molecule and the kinetic theory of gases.

Optional: The three states of matter. Physical qualities of matter. Absorption of air in water, of carbon dioxide in water, of ammonia in water, of carbon dioxide in charcoal, of hydrogen in platinum. Diffusion of illuminating gas, ammonia, and perfume into air and of sulphuric acid in water.

III. Forces Exerted by Molecules on One Another.

Required: Definition and illustrations of surface tension, cohesion, adhesion, and capillarity.* Hooke's law.

Optional: The water beetle. How drops are formed. The making of lead shot. Why a greased needle floats on water. Soap films. Oil on rough waters. Adhesive substances. Capillary tubes. Capillarity in wicks, blotters, sponges, towels, etc. Water rising in loose and in packed soil. Stresses and strains. Application of Hooke's law to tenson of a piece of wire. Elastic limit. Breaking strength. Factor of safety. Commercial testing machines. Stress-strain curve. Plotting of stress-strain curves. Problems involving application of Hooke's law. Detailed study of molecular physics.

IV. Liquid Pressure.

Required: Levels of liquids in connected vessels. City water systems. Upward, downward, and sidewise pressures in open containers.* Pressure of confined liquids. Pascal's law.

Optional: Water gauge on boiler. Artesian wells. Faucets. The S-trap. Hydrants, Standpipes. Water meter. Water motor. Pelton water wheel. Turbine water wheel. Bourbon water pressure gauge. Mercury water pressure gauge. Hydrostatic paradox. Pascal's vases. Problems on downward pressure and downward force. Water pressure in the ocean. Diving. Problems on sidewise pressure and sidewise force. Blaise Pascal. Hydraulic press. Hydraulic chair. Hydraulic jack. Hydraulic elevator. Hydraulic brakes. Problems involving advantage secured by the use in hydraulic appliances of pistons of varying sizes.

V. Buoyance of Liquids.

Required: Archimedes' principle. Buoyancy exerted on bodies sinking in water. Buoyancy applied to floating bodies. Use of overflow can.* Density. $D = \frac{W}{V}$ and derived formulas. Specific gravity. One method of calculating specific gravity for solids.* One method of calculating specific gravity for liquids.* The hydrometer and its uses.* Specific gravity table. Specific gravity problems.

Optional: Archimedes. The submarine. Boats. Floating dry dock.

* Items marked thus are suitable for laboratory work.

Life preserver. Water-tight compartments. Buoys. The float valve in a tank. Problems involving buoyancy exerted upon floating craft loaded and not loaded. Problems involving density-weight-volume relations. Specific gravity flask. The lactometer. Calculating specific gravity for solids by: (1) weighing an amount of water equal in volume to a given solid; (2) weighing the solid in air and then weighing it in water; (3) attaching a sinker to a solid which is lighter than water and then proceeding as above; (4) measuring geometrical solids. Measuring specific gravity for a liquid by: (1) weighing a bottle empty; then weighing it filled with water, and then weighing it filled with the liquid; (2) weighing a solid in air, then in water, then in the liquid; (3) balanced column method.

VI. **Air Pressure.**

Required: Demonstration that air occupies space and has weight.* A vacuum. Normal air pressure. The lift pump.* The siphon.* The mercurial barometer.* The barometer and altitude. The barometer and weather forecasting.* Aneroid barometer. Boyle's law.* Problems involving pressure-volume relations.

Optional: Principle of the vacuum pump. Vacuum cleaning system. The vacuum cleaner. The self-filling fountain pen. The pneumatic ink-stand. Determining the weight of air. The Magdeburg hemispheres. Otto von Guericke. Evangelista Torricelli. History of invention of the mercurial barometer. Constructing, calibrating, and recording results of a mercurial barometer. The barograph. Weather maps. U. S. Weather Bureau. Robert Boyle. The air compressor. Air brake. Door check. The air spring. Air rifle. Diving bell. Caisson. Pneumatic riveter. Pneumatic drill. Sand blast. Force pump. Steam pump. Fire engine. Gasoline filling station pump. Tire pump. Tire gauge. Cartesian diver. Aspirating siphon. Intermittent siphon.

VII. **Buoyancy of Air.**

Required: Archimedes' principle. Balloons. The lift of a balloon.

Optional: Dirigibles; gases used in balloons. Air planes. Instruments for recording altitude.

VIII. **Composition and Resolution of Forces.**

Required: Principle of parallelogram of forces.* Equilibrant, resultant, and component with problems.

IX. **Acceleration and Gravitation.**

Required: Force, velocity, acceleration, time. Problems on velocity-acceleration-time relations under constant acceleration ($V = at$). Average speed. Distance covered. Problems on these relations ($S = \frac{1}{2} at^2$). The force of gravity. Acceleration of freely falling bodies. Acceleration and distance covered by bodies falling along inclined plane.* Problems on falling bodies. The pendulum. Vibration rate of pendulum under varying conditions of weight, amplitude, and length.* Center of gravity and stability.

* Items marked thus are suitable for laboratory work.

Optional: Galilei Galileo. The law of universal gravitation. Weight. Gravity and the universe. Tides. Negative acceleration. Trajectories and projectiles. Rifle sights. Pendulum clocks and their adjustment. History of time-keeping devices. Problems on relation of period of vibration to length of a pendulum. The metronome. How stability is secured in automobiles, bicycles, boats, vases, book supports, etc. Center of gravity.

X. Newton's Laws of Motion.

Required: Inertia. Centrifugal force.* Momentum.* Relation of momentum to the weight of the force applied and the amount of time it is applied. Action and reaction.*

Optional: Isaac Newton. The cream separator. The sugar centrifuge. The centrifugal drying machine. The governor on machinery. Looping the loop. The gyroscope. Centrifugal force acting on heavenly bodies. Poundal and dyne. Problems on measurement of force ($F = \frac{mv}{t}$ or $F = ma$). The "kick" of a gun. The oscillating fan.

XI. Energy. Work. Power. Friction.

Required: Potential and kinetic energy. Transformation of energy. Conservation of energy. Work. Foot-pound.* Power. Horsepower. Water power. Problems on measurement of work and power. Values and disadvantages of friction.

Optional: Herman von Helmholtz. James J. Joule. Computing value of kinetic energy ($KE = \frac{1}{2} MV^2$). Perpetual motion and perpetual motion machines. The erg. The Prony brake. Rating horsepower of automobile engines. Rolling and sliding friction. Ball bearings. Lubrication. Coefficient of friction. Efficiency of machines.

XII. Simple Machines.

Required: The three types of levers.* Wheel and axle as a form of the lever. Principle of moments with problems. Mechanical advantage. Fixed and movable pulleys.* Inclined plane.* Wedge as a form of inclined plane. Screw.* Gear wheels.*

Optional: Illustrations of simple machines: butcher's scale, trip scale, chemical balance, hammers, doors, automobile brakes, automobile jacks, capstan, windlass, derricks, lifting crane, skids, road grades, vices, propellers, jackscrews, micrometer, caliper, automobile transmission, differential and steering mechanism. Differential pulleys. Advanced problems on principle of moments and mechanical advantage.

XIII. Expansion Due to Heat.

Required: Expansion of solids.* Varying expansion in a compound bar.* Coefficient of expansion. Problems on expansion of solids. Expansion of liquids.* The principle of the mercurial thermometer. Centigrade and Fahrenheit scales with problems.

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* Items marked thus are suitable for laboratory work.

Expansion of gases.* Absolute temperature scale. Charles' law. Relations of volume, pressure, and temperature of gases (when temperature is kept constant, or when pressure is kept constant, or when volume is kept constant). The gas equation and problems.

Optional: Ball and ring. Measuring linear expansion. Metallic thermometer. Recording thermometer. Thermostat. Compensation in the balance wheel of a watch. The mercury pendulum. Radiator valves. Expansion in rails and bridges. Expansion of glass. Invar. Coefficient of cubical expansion of solids and of liquids. Calibration of a mercurial thermometer. Testing the freezing and boiling points of a laboratory thermometer. The clinical thermometer. Maximum and minimum thermometer. Expansion of water and density at 4°C. See Division VI of the Chemistry course for material on gases and their measurement. Explosions and expension. Air thermometer. Standard hydrogen thermometer. The hot-air engine.

XIV. Sources and Theory of Heat.

Required: Sources of heat.* The molecular theory of heat.*

Optional: The sun as a source of heat. Heat in the interior of the earth (volcanoes, geysers, hot springs, etc.) Fuel and review of hydrocarbons. Heat produced by electric current. Friction, percussion, and compression as producers of heat. Fire by friction. Hot box. Tinder box. Pocket cigar lighter. Review of the molecular theory as studied in other sciences. Count Rumford. John Tyndall.

XV. Transmission of Heat.

Required: Conductivity of solids, liquids, and gases.* What convection is and how it operates.* Heating and ventilating.* Heat effects not due to conduction and convection; i. e., radiation.* How heat reaches us from the sun. Reflection and absorption of heat.* The thermos bottle.*

Optional: Illustrations of good or poor conductivity in wooden handles, wire handles, asbestos, Davy's miner's lamp, fur and woolen clothing, fireless cooker, air space in the walls of a house, double windows. How a room is heated by a stove. Hot-air system of heating. Hot water tank for kitchen and bath. Steam heating. How the draft in a chimney is maintained. Value of the draft. Heat economizers. Water cooling system of an automobile. Window ventilation. Mechanical ventilation. Winds. Temperature on cloudy and on clear winter days. The radiometer. Thermoelectric detectors. The ether. The Dewar flask.

XVI. Melting. Freezing. Boiling. Vaporization. Evaporation.

Required: Melting point of ice and freezing point of water. Solidification and contraction. Expansion of water when freezing.* Heat of fusion of ice.* The principle of boiling. Effect of pressure upon freezing, melting, and boiling points.* Distillation.* Heat of vaporization of water.* Relation of this fact to

* Items marked thus are suitable for laboratory work.

steam heating. Cooling effect of evaporation.* Temperature and rate of evaporation. Humidity and condensation. Low temperatures secured by evaporation and expansion. Manufacture of ice.

Optional: Melting and freezing points of liquids other than water. Alcohol in the automobile radiator. Expansion of type metal and cast iron when solidifying. Cooling water below 0°C. before allowing it to freeze. Principle of the refrigerator. Cold storage. Heat given out when water freezes. Freezing of ice cream. Freezing mixtures. Boiling points of liquids other than water. Products of distillation of petroleum. Use of vacuum pans in refining sugar and in condensing milk. Pressure cookers. Steam kettles. Vapor system of steam heating. Vacuum system of steam heating. Principle of porous water vessels and canvas water bags. Electric towels. Saturation. Relative humidity. Wet- and dry-bulb thermometers. Dew point. Clouds. Fog. Rain. Snow. Hail. Frost. Air cooling of buildings.

XVII. Engines.

Required: Principle of the slide-valve engine.* Principle of the steam turbine. The four-cycle gasoline engine.* Multiple cylinder internal combustion engines. The carburetor. Diesel engine. Cooling of gas engines. Mechanical equivalent of heat.

Optional: Hero's engine. Newcomer's engine. Non-condensing and condensing types of slide-valve engines. Corliss type engine. Compound, triple, and quadruple expansion engines. The uniflow engine. Fire tube boilers. Water tube boiler. Methods for securing drafts. Efficiency of steam engines. DeLaval turbine. Parson's turbine. Advantages of the turbine over the reciprocating steam engine. The jet type carburetor. The two-stroke gasoline engine. Kerosene engines. Air-cooled motor. The Wright whirlwind motor.

XVIII. Magnetism.

Required: Lodestone and artificial magnets.* Magnetic lines of force.* Repulsion and attraction of poles.* Magnetic induction.* The earth as a magnet. The compass.* Molecular theory of magnetism.

Optional: William Gilbert. Magnetic substances. Permeability and reluctance. Preparing blue-prints of lines of force. Declination. Dip of the magnetic needle. Manufacture of permanent magnets. Uses of permanent magnets. Magnetic screen.

XIX. Static Electricity.

Required: Electrification by friction.* Attraction and repulsion of charges.* Positive and negative electricity. Conductors and insulators. The electroscope and charging by induction.* Electrophorus and electrostatic machine. The Leyden jar and condensers in general.* The lightning rod. The electron theory.

Optional: Origin of the word "electricity." Distribution of electric charge on a conductor. Ellipsoidal conductor. Commercial con-

* Items marked thus are suitable for laboratory work.

densers and their uses. Electric whirl or tourniquet. Benjamin Franklin and his electrical experiments. Cause of electrification of thunder clouds. Sir Joseph Thomson.

XX. **Electric Currents and Electrochemistry.**

Required: Electric currents contrasted with electrostatics. The electron theory applied to electric currents. The one-fluid cell.* The principle of the primary cell. Polarization, its causes and remedies. The dry cell.* Principle of the storage cell. The lead storage battery.* Uses and care of lead storage cells. The principle of electrolysis. Electrolysis of a copper sulphate solution.*

Optional: Alessandro Volta. The Daniell cell. The gravity cell. The Laclanche cell. Local action. Laboratory construction and use of various types of cells. The Weston cell. The Edison storage cell. Electrolysis of water. Electroplating. Electrotyping. Refining of metals by electric current.

XXI. **Electric Circuits and Ohm's Law.**

Required: Open and closed circuits.* Uses of cells for open and closed circuits. Ampere. Volt. Ohm. Explanation of quantity, pressure, and resistance in analogy with water. Ohm's law.* Series circuits with problems based on Ohm's law. Parallel circuits with problems based on Ohm's law. Cells connected in series and parallel.*

Optional: Andre Ampere. Georg Ohm. Internal resistance of cells. Results from various series, parallel, and series-parallel arrangements of cells. Resistance of wire. Resistance of conductors connected in series and in parallel. Copper wire table. Effect of temperature upon resistance.

XXII. **Magnetic Properties of Electric Current.**

Required: The magnetic field around a wire carrying an electric current.* The right hand rule for lines of force.* The solenoid.* The right hand rule for polarity. The electromagnet.* The magnetic hoist. The electric bell.* The telegraph. The telephone.

Optional: H. C. Oersted. Samuel B. Morse. Strength of electromagnets. The circuit breaker. The telegraph relay. A telegraph system. The annunciator. The microphone. The electric printer.

XXIII. **Measuring Electricity.**

Required: Principle of the galvanometer. The ammeter and method of attaching to line.* The voltmeter and method of attaching to line.* The Wheatstone bridge.* The wattmeter. The kilowatt hour. Relation of kilowatt to horsepower.

Optional: The D'Arsonval galvanometer. The Weston galvanometer. Measurement of resistance by means of ammeter and voltmeter.

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* Items marked thus are suitable for laboratory work.

XXIV. Heat From Electric Current.

Required: Heating effect of electric current upon various kinds and sizes of wires.* Safety fuses. Electrical household appliances utilizing heat from electric current. Cost of operation of some common electric appliances brought for observation.*

Optional: Electric welding. Electric heating. Calculating efficiency of certain household appliances. The carbon arc furnace. The hot-wire meter.

XXV. Light From Electric Current.

Required: The tungsten lamp.* The carbon arc lamp. The flashlight.

Optional: Thomas Edison. The carbon lamp. The vacuum tungsten lamp. The gas-filled tungsten lamp. Cost of operating various types of incandescent lamps. The automatic feed of the electric arc lamp. The metallic arc. The mercury arc.

XXVI. Induced Currents and the Generator.

Required: Producing electric current by electromagnetic induction.* Fleming's rule for direction of induced current. Principle of the generator. Collecting rings and alternating current generator. Commutator and direct current generator. Multi-polar generators. Series, shunt, and compound generators with emphasis upon excitation of fields.* The alternator. The exciter. Cycle. Frequency. Phase. The magneto. Converting alternating into direct current by motor-generator method. The vacuum tube rectifier.

Optional: Michael Faraday. Joseph Henry. Lenz's law. Strength of the induced current. Securing steadiness of current. The drum armature. Star and delta connections of alternators. Mercury-arc rectifier.

XXVII. Electric Motors.

Required: Similarity of direct current motors and generators.* Torque. Starting box.* The series motor. The shunt motor and its uses.* The watt-hour meter. Rotating magnetic field of the alternating current motor. The induction motor.* The alternating current meter.

Optional: Fleming's rule for a motor. Lenz's law and back EMF. Racing of a series motor. Arrangement of motors in a street car. The compound motor. Efficiency of electric motors. The automobile starter. Synchronous motor. A-c commutator motor.

XXVIII. Induction Coil and Transformer.

Required: Effect of an electromagnet within a coil.* Structure and principle of the induction coil.* Use of the induction coil in an automobile ignition system. Self-induction. Structure and principle of the transformer.* Reasons for stepping voltage up or down.

* Items marked thus are suitable for laboratory work.

Optional: Function of the condenser with the induction coil. The induction coil and the local battery telephone circuit. Core type of transformer. Shell type of transformer. H-type of transformer. Efficiency of the transformer. Transmission of power. Hydroelectric power.

XXIX. **Wireless Telegraphy. Radio. X-Rays.**

Required: Oscillatory character of an electric spark. Electrical resonance. Detection of electric waves. Sending and receiving of wireless telegraphic signals. Transmission of the human voice instead of code signals. Cathode and X-rays.

Optional: James Clerk-Maxwell. Heinrich Rudolf Hertz. Discovery and measurement of Hertz waves. Microphone. Coherer. Crystal detector. Audion. Introduction of the telephone receiver into the circuit. Sending station for wireless telegraphy. Receiving station for wireless telegraphy. Guglielmo Marconi. The two-circuit set. Regenerative circuits. Audio-amplifying circuits. Detailed study of radio. (This subject should not be taken up unless at least two weeks can be given to it and equipment for laboratory observation is available.) Broadcasting. The loud speaker. Lee DeForest. Sparking voltages. Discharges in partial vacuum. Geissler tubes. Crookes tubes. The Coolidge cathode gun. The fluoroscope.

XXX. **Nature and Qualities of Sound.**

Required: Vibrating nature of sound.* Transmission of sound waves.* Transverse and longitudinal waves. Length and amplitude. Velocity of sound. Relations of velocity, wave length, and frequency. Echoes.

Optional: John Tyndall. Sound and the human ear. Speaking tube. Megaphone. Loud speaker. Automobile horn. How velocity of sound is measured. Effect of temperature and water vapor on velocity of sound. Sound ranging. Velocity of sound in water. Submarine signaling. Velocity of sound in various solids. Acoustics. Sound foci.

XXXI. **Musical Sounds.**

Required: Nature of musical sound as distinct from noise. Pitch and the siren.* Loudness and sounding boards.* Quality, fundamental and overtones.* Relation of pitch to length, tension, and weight of a string.* Length, diameter, and shape of an open (and of a closed) tube in relation to sound produced.* Resonance and resonators. Musical scale. Chromatic scale. Major and minor chords.

Optional: Doppler's principle. Koenig's monometric flames. The phonodeik. Principle of various types of stringed instruments. Principle of various types of wind instruments. Study of mechanism of organ or piano. The phonograph. The dictaphone. Sympathetic vibration. Interference. Beats. Discords. The even-tempered scale. Standard, international, and concert pitch.

* Items marked thus are suitable for laboratory work.

XXXII. Behavior and Measurement of Light.

Required: Inverted image.* Shadows and eclipses.* Velocity of light. Intensity of illumination and the law of inverse squares.* Candle power. Foot candle. Measuring candle power by photometer.*

Optional: History of development of the science of light. The pinhole camera. Partial and total eclipses. Olaus Romer. Albert A. Michelson. Methods of determining velocity of light. Johannes Kepler. Proper artificial illumination. The international candle. Robert Bunsen. Bunsen photometer. Rumford photometer. Jolly photometer. Spherical photometer. Foot-candle meter.

XXXIII. Reflection. Mirrors. Refraction. Lenses. Optical Instruments.

Required: Diffuse reflection. Regular reflection and plane mirrors. Angles of incidence and reflection.* Principal focus of a concave mirror.* The convex mirror.* Virtual and real images. Refraction in water and in glass.* Explanation of refraction. Index of refraction. Critical angle.* Convex lens, principal focus and images formed.* The eye. The camera.* The microscope.* The telescope.* The stereoscope.* The periscope. Projection and motion pictures.

Optional: The kaleidoscope. Use of mirrors by magicians. Cutting of diamonds. The sextant. Spherical aberration. The parabolic mirror. The searchlight. The ophthalmoscope. The automobile headlight. The convex mirror on the automobile fender. Conjugate foci. Lens equations and problems. Chromatic aberration and its correction. Nearsightedness, farsightedness, astigmatism, and glasses. Reading glass. Compound microscope. The spyglass. Construction of telescope by the class. Astronomer's telescope. Manufacture of large lenses. Opera glasses. Binoculars. Magnifying power.

XXXIV. Color and Spectra.

Required: The solar spectrum.* The rainbow. Varying wave lengths of different colors. Primary colors. Complementary colors. Absorption, reflection, and transmission of color.* Interference of light.* The spectroscope. Frannhofer lines. Continuous spectra of solids and liquids. Bright-line spectra of gases. Spectrum analysis.

Optional: Effects of colored illumination. Mixing of pigments. Color fatigue. Three-color and four-color printing. Christian Huygens. Electromagnetic theory of light. Hertzian, infra-red, light, ultra-violet, and X-rays. Polarization of light. Kirchoff's and Bunsen's work with absorption spectra. Detailed study of spectrum analysis.

* Items marked thus are suitable for laboratory work.

The Differentiated Course

Mastery of Required Topics Essential

The required topics included in this syllabus have been held to what is considered an absolute minimum. No pupil should earn a passing grade in a Montana high-school physics course unless he has a working knowledge of the principles included in the required portion of the uniform course.

Optional Topics as Differentiated Work

As mentioned in an earlier paragraph, the required topics should not occupy more than two-thirds of the time in a 36-week school year. Much or all of the remaining time may profitably be given to optional topics listed under the various subjects. If this plan is followed, the optional topics should be treated in their proper relationships to the required work. Under no circumstances should twenty-four consecutive weeks be given to the required part of the course and then twelve successive weeks to optional topics.

Suggested Subjects for Study

If, after accomplishment of the required work and the concomitant completion of such optional topics as seem desirable, there still remains time for additional study, it may be found advantageous to select one or more of the following for detailed study. It will be understood that the instructor and class should feel free to substitute other subjects for those here listed:

Generators and motors.
Engines of various kinds.
Water power.
Weather forecasting.
Radio.
Radium and radio-activity.
The automobile.
Aeroplanes and gliders.

Laboratory Apparatus

Apparatus Secured From Other Laboratories

The school in which a physics course is offered usually has a laboratory equipped for the teaching of certain other sciences; however, in preparing the following lists of laboratory apparatus, attempt has been made to include all the materials needed for teaching a satisfactory course in high-school physics. Where certain pieces of equipment have already been supplied for the teaching of other sciences, it will not be necessary to duplicate them in the physics laboratory, provided these pieces are available in sufficient quantity for the needs of the physics class.

Apparatus Lists

Lists A and B contain minimum amounts of apparatus needed for performing ordinary experiments in the physics laboratory. In supplying laboratory materials for differentiation, it will be necessary to draw upon List C. Where physics is being introduced for the first time, it may be found necessary to borrow or construct laboratory apparatus. Generally speaking, it is not educationally profitable or advantageous to borrow or construct apparatus. For this reason, all apparatus needed should be purchased as soon as practicable and in sufficient quantity to allow all members of the class to perform the same experiment at the same time.

List A—Student's Apparatus

Note: The number in the parentheses immediately following the description indicates the maximum number of pupils who may be served by the given amount of apparatus.

Quantity Recommended	Description	Approximate Price
1	**Meter Stick,** graduated to both mm and ⅛" (2)	$ .35
1	**Proctractor,** brass, 4½" dia. (1)	.25
1	**Ball,** hardwood, turned and drilled, ¾" dia. (4)	.10
1	**Ball,** lead, drilled, ¾" dia. (4)	.20
1	**Ball,** steel, ¾" dia. (4)	.12
1	**Composition-of-Force Board,** circular, all metal, including three spring balances	4.50
1	**Lever Knife-Edge Clamp,** for meter stick (2)	.35
1	**Single Pulley, bakelite,** 5 cm in dia. (4)	.70
1	**Double Pulley,** bakelite, 5 cm in dia. (4)	.45
1	**Triple Pulley,** bakelite, each pulley 5 cm in dia. (4)	.65
1	**Inclined Plane,** with pulley (6)	2.25
1	**Hall's Carriage,** frictionless cone bearings, length 17.5 cm (6)	1.50
1	**Steam Generator** (Apparatus A), one-piece boiler, no solder, cast brass gauge connections screwed to the boiler, standard steam-boiler water gauge (6)	4.50
1	**Linear Expansion Apparatus,** with steam jacket and lever arm pointer (6)	4.50
1	**Aluminum Rod,** 60 cm long (6)	.25
1	**Copper Rod,** 60 cm long (6)	.40
1	**Steel Rod,** 60 cm long (6)	.15
1	**Ball and Ring,** to show expansion due to heat	1.50
1	**Calorimeter,** drawn polished aluminum, 12.5 cm high, 7 cm dia. (6)	.85
1	**Bar Magnet,** rectangular, polished steel, 15x1.9x0.7 cm (2)	.70
1	**U-Magnet,** length 14 cm (4)	.60
1	**Compass,** 40 mm dia. (4)	.45
1	**Condenser,** 2 metal plates mounted on wooden blocks (4)	.35
1	**Electroscope,** flask form, with aluminum leaves (6)	.90
1	**Zinc Element,** flat form, 22x125 mm (4)	.05
1	**Carbon Pencil,** 6x125 mm (4)	.10
1	**Copper Element,** flat form, 22x125 mm (4)	.06
1	**Lead Element,** flat form, 22x125 mm (4)	.07
2	**Dry Cells** (dry batteries), standard size, 1.5 volts, 25 amperes on short circuit	1.00
1	**Electrolysis Apparatus,** length over all 40 cm	5.00
1	**Primary and Secondary Coil,** mounted for both vertical and horizontal positions (C) (4)	4.00
1	**St. Louis Motor,** all metal base, spring clip magnet holders, flat adjustable copper brushes (4)	3.50
1	**Electromagnet Attachment** for St. Louis Motor, essential for complete dynamo demonstrations (4)	1.25
1	**Galvanoscope,** porcelain compass block with three coils of 1, 10, and 40 turns (6)	1.75
1	**Resistance Box,** total resistance 111 ohms, coils of 0.1, 0.2, 0.3, 0.4, 1, 2, 3, 4, 10, 20, 30, and 40	12.00
1	**Resistance Coil,** 1000 ohms (8)	.50
1	**Resistance Coil,** 1 ohm (8)	.35
1	**Single-Contact Key,** simple tandem, base 5x15 cm (4)	1.35
1	**Bell,** electric, dia. of bell 2½" (4)	.75
1	**Push Button,** stamped metal, bronze finish (4)	.18
1	**Switch,** knife, single pole, single throw, 15 amperes (8)	.40
1	**Switch,** knife, on porcelain base, single pole, double throw (8)	.55
1	**D'Arsonval Galvanometer,** all metal frame, tripod with leveling screws (6)	6.25

1	**Volt-Ammeter,** D. C., full 5″ scale, range 10 volts and 10 amperes, in 0.1 volt div.	18.00
1	**Tuning Fork,** C (256 vibrations), 18.5 cm long (8)	1.65
1	**Tuning Fork,** E (320 vibrations), 17.5 cm long (8)	1.65
1	**Tuning Fork,** G (384 vibrations), 16.5 cm long (8)	1.65
1	**Prism,** equilateral, 25x75 mm (4)	.75
1	**Mirror,** plane, 4x15 cm (4)	.15
1	**Mirror,** concave, 40 mm dia., 25 cm focus	1.25
2 pr.	**Supports,** metal, for students optical bench (4)	.50
2	**Lens Supports,** for 5 cm lenses, with support to fit meter stick (4)	.12
1	**Screen Support,** to fit meter stick (4)	.12
1	**Screen,** white Bristol board (4)	.12
1	**Candle Holder,** for 1 candle (2)	.12
1	**Balance,** Harvard Trip, agate bearings, beam weighs 10 g to 0.1 g, sensibility 5 cg (6)	12.00
1	**Spring Balance,** double scale, capacity 64 oz. in 1 oz. div., and 2,000 g in 25 g div. (1)	.85
1 set	**Weights,** brass, in wood block, 1 g to 1000 g, including 1 g, (2)2 g, 5 g, 10 g, (2)20 g, 50 g, 100 g, (2)200 g, 500 g, and 1000 g (6)	8.75
1 set	**Weights,** Universal, with hooks, 10 g to 1 kg, including 10 g, (2)20 g, 50 g, 100 g, (2)200 g, 500 g, and 1 kg	3.75
1	**Beaker,** with lip, capacity 250 cc (4)	.21
1	**Bottle,** wide mouth, 8 oz. (4)	.20
1	**Bunsen Burner,** simple form (2)	.35
	If gas is not available substitute 1 Alcohol Lamp, 4 oz. @ .55.	
1	**Wing Top,** brass (2)	.15
1	**Clamp,** burette, (2)	.55
1	**Flask,** round bottom, 250 cc (4)	.21
1	**Funnel,** glass, 75 mm dia. (4)	.34
1	**Gauze,** iron wire, 20 mesh, 5″x5″ (2)	.10
1	**Graduate,** cone shape, Metric and English graduations, 8 oz., 250 cc (6)	1.50
3 ft.	**Rubber Tubing,** white, $\frac{3}{16}$″ dia. $\frac{3}{64}$″ wall (4)	.36
1 pc.	**Tubing,** gas, flexible steel, ¼″ dia., 24″ long (2)	.30
1	**Support,** ring stand, with 3 rings (4)	1.50
1	**Thermometer,** engraved scale, -10° to 220° C, length 14″ (2)	1.75
	Total for Student's Apparatus	$124.63

List B—General Apparatus

Quantity Recommended	Description	Approximate Price
1	**Caliper,** vernier, metric and English, reads to 14 cm by 0.1 mm and 5½″ by 1/128″ (12)	$ 2.50
1	**Plumb Bob,** 5 cm long	.20
1	**Adhesion Disc,** glass, 75 mm dia.	.30
1	**Cohesion Plates Set,** glass, 7.5 cm square, with handles	.75
1	**Capillary Tubes Apparatus,** set of 7, mounted in frame	1.25
1	**Inertia Apparatus,** ball and card form	1.25
1	**Inertia Ball,** with hooks, 75 mm dia.	1.50
1	**Acceleration Apparatus,** inclined plane with circular groove, 2 meters long, 15 cm wide	6.00
1	**Center of Gravity Apparatus,** about 15 cm across	.60
1	**Rotator,** hand form, driving ratio 8 to 1	9.50
1	**Rotator Accessories Set,** recommended minimum for all laboratories, consisting of: 1 Centrifugal Hoop; 1 Centrifugal Separator; 1 Glass Globe; 1 Centrifugal Force Apparatus; 1 Governor; 1 Combined Siren and Color Disc	20.00
1	**Cartesian Diver**	.40
1	**Siphon,** arms 20 cm and 30 cm long	.30

1	**Boyle's Law Apparatus,** improved all metal mounting, with fixed J tube and meter scale	5.00
1	**Lift Pump,** working model of glass, 37 cm long	1.50
1	**Force Pump,** working model of glass, 37 cm long	1.50
1	**Mason's Hygrometer,** wet and dry bulb thermometers and cistern	4.25
1	**Hydrometer,** for light liquids, 30 cm long	.70
1	**Specific Gravity Bottle,** capacity 50 cc	.80
1	**Hydrometer Jar,** with lip, 15″x2″	.65
1	**Overflow Can,** nickle-plated brass, 12.5 cm high, 7.5 cm	.90
1	**Battery Jar,** 6″ dia., 8″ high	.85
1	**Barometer Tube,** 2 mm bore, sealed at one end	.65
1	**Barometer,** mercurial, metric and English scales and vernier, mercury column entirely exposed	18.00
1 set	**Air Pump Accessories,** recommended minimum, containing: 1 Magdeburg Hemisphere; 1 Baroscope; 1 Bell Jar; 1 Gauge; 1 Bell in Vacuo; 1 Guinea and Feather Tube; 6 Bursting Squares; 1 Wire Guard	42.50
1	**Air Pump,** exhaust and compression	4.50
1	**Air Pump Plate,** lathe-turned surface, 21 cm dia	6.00
1	**Bell Jar,** straight form, knob top, capacity 1 gal	3.25
1	**Air Thermometer Bulb,** 5 cm dia., stem 30 cm long	.20
1	**Conductometer, four rods mounted to show conductivity** rate in brass, aluminum, iron, and copper	.75
1	**Unequal Expansion Bar,** 30 cm long	.75
1	**Thermos Bottle,** pint	2.75
1	**Convection Apparatus,** with glass side and chimneys	2.25
1	**Convection of Liquids Apparatus**	1.60
1	**Steam Engine Model,** locomotive type, large size, complete model	6.00
1	**Lodestone**	.25
1x1 lb.	**Iron Metal Filings,** finely prepared	.25
1 pkg.	**Blue Print Paper,** pkg. of 24 sheets, 4″x5″	.20
1	**Electromagnet,** dissectible, U-shaped	2.75
2	**Friction Rods,** hollow glass, 25x1.3 cm	.40
2	**Friction Rods,** wax, 25x1.5 cm	.50
1	**Silk Pad,** 20x20 cm	.50
1	**Flannel Pad,** 20x20 cm	.40
1	**Cat Skin,** half skin, about 20x20 cm	1.00
1 pkg.	**Pith Balls,** with silk threads, pkg. of 6, 5 mm dia	.40
1	**Electrophorous,** small disc 10 cm dia., hard rubber plate 20x20 cm	1.50
1	**Leyden Jar,** 20x10 cm, capacity 1 qt	3.25
1	**Discharger,** with rubber handle	1.00
1	**Proof Plane,** nickel-plated brass disc, insulating handle 12.5 cm long	.30
1	**Gotham Demonstration Cell,** with metric etched scale	4.50
1	**Daniell Cell,** quart size	1.00
1	**Bell Ringing Transformer,** for 110-125 volts A. C., 3⅞″x 2½″x2″	2.00
1	**Telegraph Key**	2.75
1	**Telegraph Sounder,** Standard Commercial Form, Resistance 5 ohms	3.00
1	**Telephone Receiver,** demonstration form, completely dissectible, resistance 75 ohms	2.25
1	**Telephone Transmitter,** commercial type	2.50
1	**Lamp Board Rheostat,** for 110 volt circuit, includes six lamps from 4 to 50 candle power, individual switches, fuse box, fuses, knife switch, lamp board, and plug (Where commercial current is not available, specify: 1 Lamp Board Rheostat without lamps, $10.00, and 5 Incandescent Lamps, 6 volts, $3.25)	20.00
1	**Wheatstone Bridge,** slide wire form, 1 meter long	6.00
1	**Voltmeter,** A. C., 35 to 150 volts by 1-volt div	9.50
1	**Ammeter,** A. C., portable laboratory type, Bakelite case, dust-proof, 3″ scale, 2.5 to 10 amperes net	9.50

1	**Organ Pipe**, all metal, with sliding piston, 90 cm long....	7.50
2	**Glass Tubes**, resonance, 4x45 cm	.90
1	**Sonometer**, 2-string, and resonance case	8.25
1 set	**Demonstration Lenses**, 38 mm dia., set of 6	1.75
1	**Mirror**, convex, 40 mm dia., 25 cm focus	1.25
1	**Optical Disc**, etched metal dial, complete with lenses....	22.50
1	**Universal Source of Light**, for use with optical disc, sliding rheostat, controlled brilliancy	15.00
1	**Camera Obscura**, or pin hole camera	2.25
	Rubber Stoppers	
1 lb.	**Glass Tubing**, 6.5 mm outside dia.	.70
1	**Thermometer**, engraved scale, 10° to 220° F, length 12″....	1.25
1 spool	**Copper Magnet Wire**, No. 22, D. C. C., 1 lb. spool (10)....	1.30
1 spool	**Copper Magnet Wire**, No. 24, D. C. C., 1 lb. spool (10)....	1.65
1 env.	**Co-ordinate Paper**, metric ruled in cm and 2mm, 24 sheets in env., 7¾″x9¾″	.15
*1x9 lbs.	**Acid Sulphuric** C. P. Concentrated	2.00
1x5 lbs.	**Copper Sulphate** Technical Crystals	.80
1x5 lbs.	**Mercury Metal** Virgin Grade	12.00
1x1 lb.	**Sal Ammoniac** (Ammonium Chloride) Pure White Granular	.30
1x1 lb.	**Zinc Sulphate** Pure Crystals	.30
	Total for List B—General Apparatus	$299.30

* Chemicals marked (*) cannot be shipped by parcel post.

List C—Additional Desirable Apparatus

Quantity Recommended	Description	Approximate Price
1	**Caliper**, combination, outside-inside, 6″ long	$ .50
1	**Caliper**, micrometer, metric, 0 to 25 mm without ratchet stop	5.50
1	**Liter Block**, with ruled lines, dissectible	4.25
1	**Surface Tension Apparatus**	.70
1	**Hooke's Law Apparatus**, mirror scale, spring, and weight holder (C)	1.50
1	**Wheel and Axle**, bakelite, diameters of wheels in ratios of 1, 3, 5, and 7	3.75
1	**Gear Wheels Apparatus**, wheels 5 cm in dia.	8.00
1	**Jack Screw Model**, range 3 cm, capacity 1000 lbs.	1.50
1	**Metronome** (B)	6.00
1	**Simple Pendulum**, with stand, 3 pendulum bobs, and clamp	4.50
1	**Witch**, 3 cm long	.20
1	**Second-Law-of-Motion Apparatus**, plunger and spring type	3.65
1	**Savart's Toothed Wheels**, four, 7.5 cm dia.	3.25
1	**Constant-Level Apparatus**, 4 tubes, 15 cm high	1.10
1	**Pascal's Vase Apparatus**, improved form. Heavy oil silk diaphragm. Highest accuracy	16.50
1	**Liquid-Pressure Gauge**, convenient manometer-thistle-tube combination showing pressure in all directions	1.35
1	**Hydraulic Press**, working model of glass	2.25
1	**Compression Faucet**, cut away to show working parts, net	4.50
1	**Fuller Ball Faucet**, cut away to show working parts, net	4.50
1	**Archimedes' Pump**	7.50
1	**Specific Gravity Specimens Set**, 10 in set, each about 1 cm	.65
1	**Aneroid Barometer**, metric and English scales, for altitudes up to 3,500′ (for high altitudes a special barometer is needed)	10.00
1	**Vacuum Gauge**, registers from 15 cm downward	14.00
1	**Bacchus Illustration**, two 4 oz. bottles connected by a bent glass tube	.70
1	**Water Hammer**, exhausted tube 25 cm long	1.10

1	**Tyndall's Specific Heat Apparatus,** new form, consisting of 5 balls of different metals, a rod for holding balls, a cake of paraffin, a tin molding pan, and a rectangular support for the paraffin cake	3.75
1	**Pulse Glass**	.90
1	**Maximum Density of Water Apparatus**	6.50
1	**Critical Tube,** to show action at the critical point	1.50
1	**Radiometer,** one set of vanes	2.25
1 pr.	**Parabolic Reflectors,** 25 cm dia., mounted on support rod and tripod	13.50
1	**Gas Engine Model,** 4-cycle, with miniature bulb to indicate spark, with poppet valves and mechanism for advancing and retarding the spark	14.50
1	**Lifting Magnet,** commercial form of electromagnet	4.25
1	**Magnetic Needle,** mounted, 15 cm long	.65
1	**Dipping Needle,** 8 cm, mounted with graduated arc	3.50
1	**Toepler-Holtz** Static Machine, stationary glass plate 14" dia.	35.00
1	**Friction Rod,** vulcanite, 25x1.3 cm	.40
1	**Faraday's Bag,** mounted on insulating stand 15 cm high	1.50
1	**Induction Cylinder,** fitted with 2 rods carrying pith balls	4.00
1	**Ellipsoidal Conductor**	6.50
1	**Electric Whirl,** 10 cm dia.	1.35
1	**X-Ray Tube,** 7 cm bulb	9.00
1	**Geissler Tube,** with fluorescent glass	.75
1	**Gravity Cell,** closed circuit cell, gallon size	1.50
1	**Plunge Battery,** 4 cells, in case with handles	22.50
1	**Storage Battery,** portable type, 6 volts, 60 ampere hours	18.00
1	**Completely Dissectible Dynamo,** wound for 12 volts and 72 watts	80.00
1	**Electric Motor,** color top	1.75
1	**Magneto Electro Generator,** gear driven, mounted on base with incandescent lamp	9.00
1	**Universal Motor,** A. C. or D. C., 110 volts, ⅛ H. P.....net	23.50
1	**Transformer,** laboratory type, capacity 150 watts, (if 110 A. C. is available)	7.50
1	**Model Wireless Outfit,** complete demonstration sending and receiving set	18.50
1	**Telegraph Pony Relay,** 20 ohms resistance	4.75
1	**Galvano-Volt-Ammeter,** full 5" scale, six meters in one. ranges 125 volts, 5 volts, 20 amperes, 25 millivolts, 25 milliamperes, galvanometer scale, glass front, iron case, with adjustable tripod mounting	50.00
1 set	**Sympathetic Forks,** mounted on highly resonant cases	17.50
1 set	**Acoustic Tubes,** Quincke's, set of 8	3.25
1 set	**Chladni's Plates and Holder**	2.50
1	**Newton's Rings Apparatus**	2.50
1	**Iceland Spar,** medium-sized double-refracting crystal	.35
1	**Photometer,** Bunsen's, including meter stick, supports, gas burner, candle holder, Bunsen box with screen	4.25
1	**Object and Marker,** to fit meter stick	.12
1	**Refraction Tank**	7.75
1	**Spectroscope,** direct vision form	18.00
1	**Calcium Chloride Tube,** U-form, 10 cm long	.20
1	**Condenser, Liebig's,** glass, 500 mm long (C)	1.40
1	**Funnel Tube,** thistle top, straight stem, 30 cm long	.15
1	**Graduate,** cylindrical, graduated up and down, 500 cc by 5 cc	1.60
1	**Linen Tester,** ¼" opening	.50

Total for List C—Additional Desirable Apparatus....$514.32